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Slow or Controlled Release Glass Fertilizer Containing Macro and Micro Nutrients with their Leaching Mechanistic Aspect: An Inner View

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Review Article

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ABSTRACT

Glass fertilizers or vitreous fertilizers are new type of advanced and controlled released fertilizer and made of glass matrix with low and controlled solubility in water (made of macro elements K, P, Mg, S, Ca most useful for plants) and also incorporated with micro-nutrients or trace elements containing B, Fe, Mo, Cu, Zn, Mn which are important to the growth and development of corps or plants. In a single type of fertilizer can be embedded almost all useful elements for plants; the controlled rate of solubility in water can be adjust easily by changing the composition of glass matrix. When the glass fertilizer spread in the soil, it offers the nutrients as much as the plant needed for months to year, and those advantages will cause the greater possibility for the application of glass fertilizer. In the present paper author try to explain different types of Glass Fertilizers prepared from different batch oxides mixtures as well as their leaching mechanistic aspect

INTRODUCTION

Mahatma Gandhi said real India lives in its villages and that village is the main home of farmers and the farmers are mainly depended on agriculture. Several studies have shown that global crop production needs to double by 2050 to meet the projected demands from rising population, diet shifts, and increasing biofuels consumption. Boosting crop yields to meet these rising demands, rather than clearing more land for agriculture has been highlighted as a preferred solution to meet this goal. However, we first need to understand how crop yields are changing globally and whether we are on track to double production by 2050. In the agriculture field farmers use huge amount of different types of fertilizers for increasing the yield of corps production. Large scale applications of fertilizer nitrogen (N) have also shown deleterious effects on ground water quality, especially its nitrate content, which is harmful to health. Furthermore, gaseous losses of N as NH3 and NOx resulting from N fertilization have adverse effects on the environment.

Therefore, the goal of all agriculture has to be to “increase food-grain production with the minimum and efficient use of chemical fertilizers”. This calls for a sincere effort on the part of agricultural scientists including extension workers to increase the efficiency of fertilizers applied in the farm fields. Here different types of slow or Controlled Release Fertilizers (CRF) including Glass Fertilizer were described with their nutrients release mechanism. The environmental hazardous effects, i.e., disadvantages of different common commercially available fertilizers and advantages of organic fertilizer and controlled release fertilizers including Glass Fertilizer over common inorganic fertilizers properly explained here. There are numerous crops and plants which have different growing habits and nutrient requirements. The blended mixtures of measured quantities of the nutrients enable the plants to get potential nutrition and help them to hasten growth and yield more than their usual capacity.

LITERATURE REVIEW

The fertilizers are highly soluble and do not take much time to get dissolved in the soil and reach the plant in no time. However, it happens only in the case of chemical fertilizers and organic fertilizers take time to be dissolved. Moreover, agricultural fertilizers are a combination of hazardous and beneficial fertilizers. Organic fertilizers are not as harmful as the inorganic ones however the former takes more time than the latter to reach the roots of the concerned plants. Excessive fertilization does encourage great yields however also invites air, water and soil pollution. Therefore, it is very necessary to use fertilizers in limited quantities and if possible then organic and inorganic should be used simultaneously to counterattack the miscellaneous soil hazards. Glass fertilizers are new type of advanced and controlled released fertilizer and made of glass matrixes with macro elements (K, P, Mg, S, Ca) most useful for plants and also incorporated with microelements (B, Fe, Mo, Cu, Zn, Mn) which are important to the growth and development of corps or plants.

The quantity of the microelements incorporated in the glass as oxide in the range 1-5%. The use of glass fertilizers offers lot of advantages: due to low or controlled solubility it avoid underground water pollution; the soil pH can be regulate by the pH of the glass matrix, do not release acid anions (Cl-, SO2-) which are harmful for plants so there is no risk of soil burning when they are incorrectly dosed, in a single type of fertilizer can be embedded almost all useful elements for plants, the controlled rate of solubility in water can be adjust easily by changing the composition of glass matrix.

In addition as the leach resistant of glass is very high i.e. when applied to a soil the fertilizer will be released very slowly satisfying the optimum level of requirement and no misuse there. It has been found that when such a fertilizer is applied on tree like mango remain 20-25 years at the root and it will grow and give fruits with a single charge of fertilizer.The natural or synthetic, chemical-based substance of various essential minerals and elements meant for the regular as well as hastened growth and nourishment as well as fertility of all plants is termed as fertilizer. As these fertilizers have been used invariably to promote and enhance the productivity of commercial crops, therefore they are called agricultural fertilizers.

Fertilizers enhance the richness of the soil and nourish it with required nutrients. By enriching the soil, fertilizers also increases the productivity of the crops. Fertilizers are the nutrient filled sources which nourish the plants with essential nutrients and soil acts as a medium between the crops and the fertilizers. A substance (Such as manure or a special chemical) that is added to soil to help the growth of plants.

Fertilizers are composition of one or various chemical compounds or nutrients therefore depending on the constituent compounds and nutrients release mechanism, the agricultural fertilizers have been categorized into following categories:

Organic agricultural fertilizer: Organic fertilizers are those fertilizers which are manufactured using organic substances which are bio-degradable, i.e. Organic fertilizers are naturally occurring fertilizers and nutrient enhancers of the soil. Therefore every substance that occurs naturally and is easily bio-degradable is organic and if this organic material enhances the richness of the soil, it is termed as organic fertilizer.

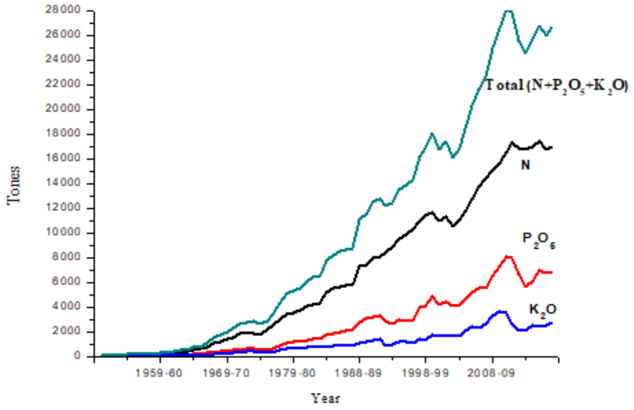
These organic substances are further decomposed and broken into smaller and soluble particles by numerous microorganisms. After being turned into soluble and simpler compounds, these fertilizers are taken in by the roots. Manure, slurry, worm castings, peat, seaweed, sewage, and guano are the naturally occurring Green manure and compost, blood meal, bone meal and seaweed extracts, etc. are manufactured organic fertilizers.

Crops are also grown to add nutrients to the soil. Today what each farmer is looking forward to be proper solution to agriculture problem without compromising on the yield. Today the use of fertilizers is one of the greatest innovations of the agricultural revolution.

Inorganic agricultural fertilizer: Those fertilizers which are constituted by inorganic chemical substances are referred to as inorganic agricultural fertilizers, i.e., granular triple superphosphate, potassium chloride, urea, anhydrous ammonia, etc. These fertilizers are usually non-biodegradable. And these are further divided into various categories based on their constituents and methods of preparations.

These fertilizers are also called artificial or synthesized fertilizers as they are manufactured in the factories using latest technologies. The artificial manufacturing processes render these fertilizers a rough touch and propel them to be sturdy and highly per-formative. From the data of the Fertilizer Association of India (FAI), Delhi it is clear that the consumption of NPK type fertilizers in India rapidly increases (Figure 1).

Figure 1. All India Consumption of N, P_2O_5 and K_2O.



Advantages of chemical inorganic fertilizer:

- Readily available: as the most common form used, it is found everywhere.
- Formula variety: it is easy for chemical companies to vary the elements to produce blends for different seasons and for specific plants.
- Fast acting. Usually see results within 1-2 weeks if the formula used is appropriate for the season.
- Inexpensive: typically, except for the better quality blends that have controlled release pellets.
- Ease of application: using fertilizer spreaders. Rates and settings are usually calculated and displayed on bag.
- Multiple forms: available in pellets, granules, liquid, tablets, spikes and slow-release, to suit every preference.
- They are quite high in nutrient content; only relatively small amounts are required for crop growth.

Disadvantages of chemical inorganic fertilizers:

- Water soluble in most forms. Since water releases the nutrients, it is not uncommon to lose one-third of the nutrients by leaching out of the soil before the plant can access them.
- Short life span, unless using a controlled release form.
- Doesn’t build up the soil. The basic synthetic elements contribute nothing to enhance soil fertility.
- May decrease soil fertility. Chemical nitrogen stimulates the growth of existing microorganisms, which then use up organic matter in the soil. Repeating this cycle regularly leaves soil depleted.
- Excess growth can occur with some varieties or with surplus application. This results in more mowing or pruning, places stress on roots, causes heavier grass stains on clothes from lawns.
- Danger with incorrect application. Potential of harm from excess, especially lawns getting coverage overlap.

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- Salt burn risk. Synthetic fertilizer is salt. Over application can result in negative effects such as leaching, pollution of water resources, destruction of micro-organisms and friendly insects, crop susceptibility to disease attack, acidification or alkalization of the soil or reduction in soil fertility thus causing irreparable damage to the overall system.
- Trace nutrients missing, in many synthetic blends. Excess of major nutrients can bind up other nutrients in the soil, making them unavailable to the plant.
- Environmental problems occur with chemical run-off.
- Excess phosphorous can collect in the soil and cause pollution problems.
- **Nitrogen is volatile:** is lost easily into the atmosphere when fertilizer is left on the ground and not watered into the soil. It is also lost from bags in storage, if not sealed properly.
- Absorbs moisture easily in storage. This results in caking, or hard fertilizer, which is difficult or impossible to use.
- Iron stains. When added to formula, it is water soluble and can leave rust stains on concrete if not handled correctly.
- High energy consumption required to produce these products [10]
- **Eutrophication:** Overgrowth of aquatic vegetation and degradation of water quality due to extra nitrogen accumulation.
- **Increased acidity:** Many chemical fertilizers are composed of acids like sulphuric acid and hydrochloric acid and these acids decrease the soil's quality and heighten the acidity which further registers a bad impact on the plant growth.
- **Loss of bacteria:** The natural nitrogen fixing bacteria, rhizobium suffers great blows from the excessive usage of chemical bacteria.
- Certain plants are hampered due to excessive dozes of the chemical fertilizers so much so that they also tend to cease growing and yield fruits.
- Synthetic fertilizers may be fast-acting but they come with a price.

Macronutrients fertilizers

The concentration of each fertilizer in the dry base determines their strength and also their constituent elements. There are six main and most prominent elements which play a vital role in the growth of the plants. Nitrogen, phosphorus, and potassium are primary macro-nutrients.

These macro-nutrients are very essential for the proper and anti retarding growth of any plant and further these nutrients enhance the yields by great differences. Calcium, magnesium, and sulphur come under the category of secondary macro-nutrients. Although all these nutrients are required by the plants in almost similar quantities however their availability marks the difference.

Micronutrients fertilizers

Plants also need certain nutrients in little but essential quantities and absence of these elements might hamper the growth in an effective manner. The plant growth can be retarded and can show a lasting impact on the yields as well. However, the micro-nutrient fertilizers are meant to serve the lessened but necessary needs of the plants and therefore these fertilizers are aimed at providing little portions of nutrients like iron, manganese, boron, copper, molybdenum, nickel, chlorine and zinc. The concentrations in which these elements are needed range vividly from 5-100 ppm. The essential plant nutrients (macro and micro), their forms taken up and their typical concentration in plants are shown in the Table 1 and effect of pH plant nutrient availability.

Table 1: Essential plant nutrients, forms taken up and their typical concentration in plants.

Nutrient (symbol)	Essentiality by	Established forms absorbed	Typical concentration in plant dry matter
Macronutrients			
Nitrogen (N)	De Saussure (1804)	NH_4^+, NO_3^-	0.015
Phosphorus (P, P_2O_5)	Sprengel (1839)	$H_2PO_4^-$, HPO_4^{2-}	0.1–0.4%
Potassium (K, K_2O)	Sprengel (1839)	K^+	1–5%
Sulphur (S)	Salm-Horstmann (1851)	SO_4^{2-}	0.1–0.4%
Calcium (Ca)	Sprengel (1839)	Ca^{2+}	0.2–1.0%
Magnesium (Mg)	Sprengel (1839)	Mg^{2+}	0.1–0.4%
Micronutrients			
Boron (B)	Warington (1923)	H_3BO_3, $H_2BO_3^-$	6–60 µg/g (ppm)
Iron (Fe)	Gris (1943)	Fe^{2+}	50–250.µg/g (ppm)
Manganese (Mn)	McHargue (1922)	Mn^{2+}	20–500.µg/g (ppm)
Copper (Cu)	Sommer, Lipman (1931)	Cu^+, Cu^{2+}	5–20.µg/g (ppm)
Zinc (Zn)	Sommer, Lipman (1931)	Zn2+	21–150.µg/g (ppm)
Molybdenum (Mo)	Arnon& Stout (1939)	MoO_4^{2-}	below 1.µg/g (ppm)
Chlorine (Cl)	Broyer et al., (1954)	Cl^-	0.2–2 percent

The controlled release fertilizers must be, therefore either 'slow-releasing' or must contain nutrients in exchange sites. Slow releasing or controlled releasing fertilizers are the latest concept in fertilizer technology. The compounds from which plants roots can extract ions by exchange reactions, and compounds which undergo hydrolysis and solubilization at optimum rate to fulfill the requirements of the plants, are suitable as fertilizers. A real controlled-

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releasing fertilizer can only be formulated at the molecular level. In recent use there have different types of slow or controlled release fertilizers some of them are as follow:

- Sulphur Coated Compound Fertilizer
- Sulphur Coated Urea (SCU)
- Resin Coated Fertilizer
- Urea formaldehyde
- Urea and Nitrification inhibitors
- Chemically Modified Biomass Coating Urea for Controlled Released
- Glass fertilizer

Advantage of the controlled release fertilizers

The slow-release fertilizer is an environmental-friendly fertilizer which can slow down or control the nutrient release rate, to reduce nutrient loss and increase fertilizer use efficiency.

- Increase fertilizer use efficiency. Generally speaking, slow/controlled release fertilizer can increase fertilizer, use efficiency by 10-30% compared with instant nitrogen.
- Decrease fertilizer application rate and save labor. Slow/controlled release fertilizer can produce the same yield with the rate 10-40% less than conventional fertilizer. Sometimes, only single application is required, which can reduce labor cost by 75%.
- Reduce environmental pollution caused by fertilizer. To increase fertilizer use efficiency with slow/controlled release technology equals to the increase in fertilizer production. The current urea production in China is approximately 20 million tonnes, if coated with sulfur, the nitrogen use efficiency can be improved by 20%, which means the urea production is increased by 4 million tonnes.
- Each element contained in controlled release fertilizer has an effect to give a very high increase in the fertility of the soil, each nutrient of CRF is not water-soluble yet easily soluble in weak acidic content in the soil or generated by plant roots.
- The CRF neutralize toxic acids in the soil and from other fertilizers.
- Controlled release fertilizer is very convenient for use and can be store for a long time because it does not absorb moisture, does not disintegrate even in damp.
- Glass fertilizer does not contain toxics substances, since it does not have an acidic sulphate or chloricradical, glass fertilizer does not cause acidity to the soil, toxic gas or hydro sulpharic that can destroy plant roots on rice-fields. Normally, the soil is poor in phosphate (P_2O_5), therefore, P_2O_5 is necessarily to be added. P_2O_5 is the important constituents of plant root cells which assist the roots in growing strongly thus further improving the yield. The glass fertilizer is not water-soluble, it lies within the soil and continues providing necessary nutrients for the plants, meanwhile, other kinds of fertilizer are easily soluble in water, for example, super phosphate, and ammoniac sulphate can have immediate effects but are easily held by aluminum in the soil thus rapidly washed out. Plant roots still continue to dissolve P_2O_5 *via* immediate contact with glas fertilizer in the soil. This effect is very important to the type of soil originating from volcano ashes, wild soil and exhausted fields poor in P_2O_5.

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- The glass fertilizer not only helps increase the fertility of the soil, suitable for many kinds of plant but also help prevent lack of magnesium and some other nutrients in the soil that support the plant's growth.
- Mg and Ca are much in the soil but due to long-term withering in acidic alum soil, the alkali effect is void, this frequently occur in tropical and subtropical zones.

The Mg is very necessary for creating Chlorophyll in plant leaves, the main constituent of the plants. Mg plays an essential role in the production of protein and fat in plants.

Mg improves the effect of phosphate, helping plants absorb the nutrients lying inside the soil and also participate in transporting P_2O_5 that has been absorbed in the tree-trunk. Fussed magnesium phosphate fertilizer can be seen as the most suitable one in tropical and subtropical zones poor in P_2O_5.

In such zones, many kinds of nutrient of plants are in the process of washing out; this situation can be improved by using CRF fertilizer continuously, on the one hand, controlled release fertilizer helps increase the fertility of the soil, on the other, it assists the soil in maintaining the nutrients in an efficient manner.

Glass fertilizer and its preparation

Glass is an amorphous (non-crystalline) solid material. Most of the glasses are typically brittle, optically transparent, as a substance, plays an essential role in science and industry. The chemical, physical, and in particular optical properties make them suitable for applications such as flat glass, container glass, optics and optoelectronics material, laboratory equipment, thermal insulator (glass wool), reinforcement materials (glass-reinforced plastic, glass fiber reinforced concrete), glass art (art glass, studio glass) and recently as glass fertilizers for plants nutrients (macro and micro). Phosphate glasses are also known by their poor chemical durability; they offer the possibility of being completely degradable in an aqueous environment, this solubility can be controlled via their composition,which makes them of interest for use as controlled-release fertilisers.

Glass fertilizer are new type of advanced and controlled released fertilizer and made of glass matrixes with macro nutrients (K, P, Mg, S, Ca) most useful for plants and also incorporated with micro-nutrient (B, Fe, Mo, Cu, Zn, Mn) which are important to the growth and development of corps or plants. The quantity of the microelements incorporated in the glass as oxide in the range 1-5%. The use of glass fertilizers offers lot of advantages: due to low or controlled solubility it avoid underground water pollution; the soil pH can be regulate by the pH of the glass matrix; do not release acid anions (Cl , SO_2) which are malignant for plants so there is no risk of soil burning when they are incorrectly dosed; in a single type of fertilizer can be adorned almost all useful elements for plants; the controlled rate of solubility in water can be adjust easily by changing the composition of glass matrix. With the growing need for efficient utilization of resources, such glass fertilizers are most deplorable and call for a radical changes in the inorganic fertilizers.

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Several glass fertilizers compositions were prepared through a conventional glass melting process with different $SiO_2/Al_2O_3/CaO$ concentrations (in wt.%). In all cases the K_2O/P_2O_5 ratio (wt.%) was maintained at 0.65. The corresponding raw materials (silica sand, calcium carbonate, potassium carbonate, phosphorus oxide and potassium feldspar) were mixed for two hours and then melted at 13000 °C for two hours using mullite crucibles. To avoid phosphorus dissolution each GF was fritted in a metal plate, then crushed and sieved to the required grain size and stored in a desiccators until use. Grain sizes (2-3 mm), similar to conventional NPK fertilizers, were selected in order to facilitate the further application to crops using industrial agricultural machinery. In the selected glass fertilizers for fertilization of the tomato crop, the corresponding micronutrients were added at the following concentrations (wt.%): S, 0.5; Mg, 1.5; Mn, 1.4; Fe, 0.6; Zn, 0.2; B, 1.5. These micronutrients were incorporated directly as oxides during the melting stage of the glass fertilizers.

Composition of the different glass fertilizers

The composition of different glass fertilizers with various kinds of nutrients for different crops is presented. The interesting characteristic of phosphates which are used as former for glass fertilizers makes them so suitable for the production of polymeric fertilizers is that the ortho phosphate ion, i.e., polymerizes on hating with formation of linear chains of P-O-P bonds, In final stages of condensation, branches chain polymers may also be formed. Thus, in a meta-phosphate containing linear phosphate chain the negativity charged oxygen atoms may be neutralized by K^+, Mg^{2+}, Ca^{2+} or NH^{4+} ions (corps nutrients). Since these ions are held in exchangeable positions on an anionic polymer chain, they possess the dual property of being almost insoluble in water but being readily solubilized by complexants and by cation exchange. Moreover, slow hydrolysis of the P-O-P group occurs causing solubilisation of the cations. It is noteworthy that polyphosphates of all the macro- and micro nutrient ions may be prepared; additionally, their solubility can be varied to desire to levels by controlling the degree of polymerization of chain. The model Network structure of the glass fertilizers with different corps nutrients.

The schematic binding procedure of 'glass fertilizers nutrients' with the soil component and plant's root showing its network structure is presented. The different types of magnesium phosphate and their network structure formed in the magnesium containing phosphate glass fertilizers.

New Glass Fertilizers contain Macro and Micro Nutrients. Nutrient release is controlled by the chemical glass composition. Controlled-release fertilizers are fertilizers containing a plant nutrient in a form, which delays its availability for plant uptake and use after application, or which extends its availability to the plant significantly longer than the usual fertilizers. After Nutrient release new pores are formed inside the glass particles where irrigation water is absorbed to be used by the plants.

The effectiveness of nutrient release control is increasing the fertility of the soil, increasing nutrient use efficiency, reducing environmental problems caused by the excessive use of rapidly available nutrient fertilizer, matching nutrient supply with plant demand and maintaining nutrient availability for the entire season.

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Dissolution procedure of phosphate glass

Both the geochemical and thermodynamic approach to glass corrosion depend on a quantitative determination of the equilibrium, which is described by a complex solubility product changing with the amount of glass dissolved into solution. The hydration and hydrolysis processes associated with glasses in aqueous solutions have been related to the free energy changes for reactions that occur between the glass constituents and the absorbed water molecules. The relationships between the calculated thermodynamic stability and glass dissolution rates can then be used to estimate the relative glass durability in aqueous solutions. The leaching kinetics of each glass constituent is compositionally and structurally dependent.

They developed the general description for the dissolution reactions between phosphate glasses and water. The first stage of dissolution is controlled by diffusion, including penetration of H2O into the glass network and diffusion of ions through the developing hydrated layer back into solution.

Acid dissociation constant (pKa) of possible species in an aqueous solution containing Na, P, Fe, Si ions. Glass dissolution behaviour is mainly controlled by the breakdown of the glass network and extraction of alkali ions out of the glass matrix. Surface conditions and layer formation, saturation effects and solution chemistry are also taken into account. The hydration reaction between glass and H_2O is based on the hydrolytic cleavage of glass network bonds. Usually, the initial stage is controlled by the ion exchange process and then followed by the matrix dissolution with increasing depth of alkali depletion in the outer glass surface. Two main approaches, geochemical and thermal dynamic, have been used to study the glass dissolution process. Models derived from these two approaches have been applied successfully to many corrosion tests of nuclear waste glasses.

The investigation of the influence of pH on the dissolution of phosphate glasses has been experimentally. That at pH <6.5 (i.e. acidic media), phosphate glasses adsorb an excess of protons while at pH > 6.5 (neutral and basic media), excess of OH- ions are adsorbed. Accordingly, in acidic media, phosphate chains are protonated due to ion exchange reactions between Na+⇌ H+ at the beginning of the glass corrosion process, which disrupts the ionic crosslinks among phosphate chains. This allows water to penetrate into the glass faster, leading to rapid chain hydration and uniform dissolution. With respect to the apatite forming ability and corrosion of glasses, fluoride incorporation in glasses slows down their chemical dissolution in deionised water due to repolymerization of the phosphate glass network, but only until the stage where glass network structure is not broken by the attack of H^+ and molecular water.

pH prediction

There are three types of sites on phosphate anions, each with a different acid dissociation constant (pKa) that can be protonated in a leachate at an appropriate pH value: middle site 1, terminal site 2 and terminal site 3 middle site 1 has a pKa value between pH 1-2. Terminal site 3 has a pKa value around pH 12. The pKa values for terminal site 2 are sensitive to the presence of cations in solutions and vary between pH 3-11. Therefore, for phosphate

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anions in the leachate solutions with final pH values from 3 to 9 the middle sites 1 are all in anionic form and should be associated with Na^+, Fe^{2+} or Fe^{3+} and the terminal sites 3 are all protonated. Terminal sites 2 are likely partially protonated and so can have a buffering effect on the solution pH. The greater the number of middle sites 1, the more negative the surface charge of the anion will be. However,there seems to be no correlation between the surface charge and the rate of glass dissolution.

The pH value of leachates in the static dissolution test reached a constant value in the first 24 hours of glass dissolution. Since the phosphate anions are the major anions in solution, the total number of terminal phosphates in chains released to the leachate solution can be determined from the total phosphorus released and the phosphate chain length distributions, and these can then be related to the solution pH value. For a better prediction of solution pH, the charged species in a leachate, especially for phosphate anions need to be determined for different pH ranges according to their values. The values of all the possible species in an aqueous solution containing Na, P, Fe, and Si ions. From these values, the major species and buffer reactions in the leachate solutions of Na-Fe-phosphate glasses with pH range 2-7 and 7-10 can be determined. Because of high field strength, hydrated iron cations in aqueous solution attract electron density between the O and the H atoms, making weaker O-H bonds and easier dissociation of the H^+ ions from coordinated H_2O. According to the principle of charge balance in solution, total positive charge (A) equals the total negative charge (B), which can be expressed by the following equations,

CONCLUSION

Since the inception of Green Revolution there has been a race for increasing food grain (mainly cereals) production using chemical fertilizers in India. However, cereals production in the country increased only six fold, while fertilizer consumption increased 342 times during the 1950-51 to 2018-19 periods, implying very low fertilizer use efficiency. The Controlled Release Fertilizers delivers up to 10 weeks of healthy plant growth and colour, so we can make fewer applications in a season. Less product breakage means less quick release, less surge growth and longer residual feeding. The CRF can trace elements that can be fitted into slightly soluble glasses for slow release in soil. The experiments have shown a 25-50% increase in the crop production with use of these micro nutrient glass fertilizers and the benefits can be seen for over 20 years of each addition. Micro Nutrient Glass Fertilizers release micronutrient trace chemicals in soil for balanced plant growth, over a 10-20 year period, and are not easily washed away. If a mixture of phosphate rock and olivine or serpentine (magnesium silicate) is fused in an electric furnace. The molten product is quenched with water and used in a finely divided state as a fertilizer. The product, a Calcium Magnesium Phosphate (CMP) glass, contains about 40% P_2O_5, 15% MgO and 30% K_2O. Over 90% of the product is soluble in citric acid.

The minerals are variable in compositions; iron, nickel, molybdenum and sometimes manganese may substitute for magnesium. The change of the K_2O/P_2O_5 ratio is the main key factor to control water solubility, physical properties such as density and hardness and chemical durability. In the abnormal glass properties such as fast dissolution in aqueous solution, it was presented that the glass can be a good candidate for agriculture fertilizer. Most important of all, water and soil pollution hazards are minimized and the economics of fertilizer use is significantly improved.

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All this can be achieved with just cheap and readily available raw materials and using processes that are both technical simple and fairly low energy consuming. It would appear that in the long run polyphosphates are indeed the answer to the problem of choosing the right fertilizers for the needs of the future.

For maximizing health and growth of crops, plants need to ingest certain elements, such as borax, cobalt, iron, manganese and nickel in trace quantities. Use of the common salts of these chemicals do not help very much, not only because excess quantities may actually be harmful, but these salts are usually soluble in water, and are washed away with the first rain, and so, are not only wasted, but contaminate the soil nearby with excess micronutrients. Micronutrient glass fertilizers, on the other hand, contain these micronutrients in the form of slightly soluble glassy granules, which cannot be washed away easily, and dissolve into the soil slowly, so that 200gms per sq. meter of micronutrient glass fertilizer provides the required nutrients over a period of 20-30 years, for the fertilized area before replenishments are required. So this is holistic approach to the environment. It can be concluded that the glass composition and structure can be designed in order to control the solubility in water and to obtain valuable vitreous fertilizer with special application in plant production.

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