A review of controlled release fertilizers biology essay

In general, plants must be supplied with nutrients during the whole vegetation period. In horticulture this is achieved by applying quickly soluble fertilizer once to twice a week, for example. This kind of fertilizer application is very labour-intensive and requires considerable specialist knowledge, so as to select the correct rate of application, appropriate time of application and correct composition for the particular plants to ensure optimum plant production. With the use of slow or controlled release fertilizers the full amount of nutrients necessary for the whole vegetation period can be applied at the time of planting or at the earliest stages of plant growth, in the form of a nutrient pool Also, about half of the applied fertilizers, depending on the method of application and soil condition, is lost to the environment, which results in the contamination of water [1]. This kind of environmental concerns of feeding crops with traditional fertilizers has led to developing Slow Release Fertilizers (SRFs) or Controlled Release Fertilizers (CRFs). SRFs or CRFs are easy and safe to use. They reduce risk of incorrect fertilizer application; they are labour saving; and minimize nutrient losses by leaching or fixation.

The idea of producing SRFs was developed from 1963 by encapsulation of fertilizers by waxes. After that, these products have been commercialized. There are lots of SRF and CRF brands; market leader in controlled release fertilizers is Scotts Professional with key brands such as Osmocote Exact, Sierrablen and Osmoform. SunGro Company is also producing controlled release fertilizers with brand name of Multicoate. AGLUKON is also another commercialized SRF product [2-4].

Like lots of scientific fields, agriculture industry has been over shadowed by nanotechnology. Applications of nanotechnology in agriculture includes agriculture crop improvement, nanobiotechnology analysis of gene expression and regulation soil management, plant disease diagnostics, efficient pesticides and fertilizers, water management, bioprocessing, post harvest technology, monitoring the identity and quality of agricultural produce and precision agriculture[5]. Efficient pesticides and fertilizers in terms of ” Nano-composite based slow release fertilizers ” are developing in current decades. Using nanoparticles as reinforcing or cementing agent of polymer coatings has been the only feature of nano particles which is used in preparing slow release fertilizers [6, 7].

Fertilizers

Fertilizers are applied to soil to promote plant growth. They contain some beneficial nutrients including macronutrients and micronutrients. Macronutrients are nitrogen, phosphorus, and potassium which are added to soil in quantities from0. 2% to 4. 0% (on a dry matter weight basis) and are more essential than micronutrients. Micronutrients are elements which are applied to soil in much smaller amounts, ranging from 5 to 200 ppm, or less than 0. 02% dry weigh. These elements could be sulfur (S), boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn)[8, 9].

2. 2. Types of fertilizers

Fertilizers would be categorized from source of being and also from release properties points of view. All fertilizers could be organic or synthetic from source of being point of view. Organic fertilizers are naturally occurred including seaweed, worm casting, manure, slurry, peat, humic acid, guano and brassin. They provide slow release of nutrient as they need soil's bacteria to be broken down to needed elements. Also, they may improve the biodiversity of soil by supplying organic matters and micronutrients for organisms. Organic fertilizers are cheaper and safer than synthetic fertilizers [9, 10].

The main synthetic or mineral fertilizers are urea, ammonium sulphate, ammonium phosphate, phosphate rock, potassium chloride, super phosphates, calcium ammonium nitrate, potassium sulphate and NPK, PK and PK compound fertilizers. The most important drawbacks of synthetic fertilizer is their long term sustainability. Also, they are more expensive in contrast to organic fertilizers [10].

Also, fertilizers can be categorized into ordinary and controlled release fertilizers from release properties points of view.

Drawbacks of non- controlled release fertilizers

Ordinary fertilizers leach to soil very quickly and most of them are not used by the plants. According to figures " about 40-70% of nitrogen, 80-90% of phosphorous, and 50-70% of the applied normal fertilizer is lost to environment and cannot be used by plants"[11]. This rapid leaching will cause burning of plants and growing in spurts. Also, the lost elements will make some serious problems for our environment. Eutrophication, Blue baby syndrome, soil acidification, persistent organic pollutants, heavy metal accumulation, atmospheric effects are environmental concerns of ordinary fertilizers. Another result of quick leaching of fertilizer is repeating the application of fertilizers which will increase the costs[8, 12, 13].

Slow or controlled release fertilizers

Slow release fertilizers or controlled release fertilizers are coated in a substance that enables a slow release time and eliminates need for constant fertilization and higher efficiency rate than soluble fertilizers [14].

The interest in these materials is for one or more of the following reasons: Availability of nutrients during the hole growing-season; reduced nutrient loss via leaching and run-off; reduced cost and labor outlay in crop production; reduced chemical and biological immobilization reactions in soil which cause plant unavailable forms; reduction of rapid nitrification and nitrogen loss through ammonia volatilization and denitrification; reduced seed or damage from high local concentrations of salts; reduced leaf burn from heavy rates of surface-applied fertilizers; better seasonal distribution of growth and better acclimatization in home or display environment; improved storage and handling of fertilizer materials[15].

Differences between slow and controlled release fertilizers

Although there is no a special difference in general function of CRF and SRF, but it should be mentioned that they are manufactured by different materials and techniques with different properties. In slow release fertilizers elements are present in the fertilizers in a chemical form, which is not available to plants and they will be converted by physiochemical effects or microorganisms activities into nutrient forms in the soil. But in controlled release fertilizers elements are packed in coated granules and are released through the coating over a certain period of time. Also, in SRFs nutrients available period is affected by a lot of factors such as water content of soil, Ph, temperature, microorganism’s activity, aeration. However, the longevity of CRF depends on coating thickness and temperature of soil. Only coating method is effective in changing pattern of nutrients release and a fixed coating thickness control nutrients release. In CRFs declared release time refers to soil temperature of 20-21 oC. Higher temperatures accelerate the element release and lower temperatures make it longer [4, 16].

SRFs are chemically prepared slow released. Some kinds of SRFs are Urea Aldehydes (UA) and Chelated Micronutrients(CM). Common type of UAs is urea formaldehyde which is high nitrogen fertilizer. Starting release rate of UAs is high but it dies off slowly for 3 years. This kind of fertilizer depends on microorganisms to break it down for plant use. CMs are substances that hold firmly together iron, manganese, zinc, and copper. They slowly releases over a long period of time [17].

2. 4. 2. Types of CRFs

2. 4. 2. 1. Sulfur Coated (SC)

Elemental sulfur when is oxidized to its sulfate form would be one of the nutrients which is essential for some plants and is normally blended with other fertilizers. Using sulfur coating is also another way to provide sulfur simultaneously with making slow release properties for a core granular fertilizer. As the sulfur containing materials like polysulfides or lingosulfonate are brittle and also give a low wetting of defects they are normally mixed with waxes or plasticizers. Many formulas are available for SCs. Their release time is generally 3-4 months. SDs are released by microorganisms [18-22]

2. 4. 2. 2. Wax coated (WC)

One of the methods of reducing fertilizer release rate is dispersing granular fertilizers with molten wax and then cooling the mixture below the melting point of the wax [23]. Paraffin is one of the most used wax as a coating for fertilizers. Paraffin wax is a white, tasteless, odorless, waxy solid, with a typical melting point between about 47 °C and 64 °[24]. Other types of waxes are synthetic oil based, petroleum or mineral waxes. Waxes are normally used by an additive or a tackifiere agent to make a good sealing properties [25, 26]

2. 4. 2. 3. Polymer Coated (PC)

Polymer-coated fertilizers (PCF) represent the most technically advanced controlled released fertilizers. They include a water-soluble fertilizer core and one or more than one layers of polymer. There are large varieties of polymers to coat the core fertilizer also the coatings layer could be the same one or different. In PC fertilizers release of nutrients will happen by diffusion through a semi permeable polymer membrane. Water penetrates the coating and dissolves the core. Release rate can be controlled by varying the composition and thickness of the coating. In addition, pressure builds up can cause cracks to form, from which fertilizer passes into the soil [27, 28].

2. 5. Review of preparation methods of different polymer coated CRFs

2. 5. 1. Sole Polymer coated

One type of polymer coated CRFs is the one which the fertilizer core which could be N, P, K OR NPK compound, is just coated with one or more than one layer of polymer coating. In this case the polymer could be solvent based or water-based. The application process starts with dissolving the polymer in a organic solvent or water. After dissolving the coating will be sprayed onto the fertilizer in a coating drum or fluid bed [29]. Benefits of polymer coated CRFs are as follow; uniform and defect free coating will surround fertilizer; the coating will be very tough and durable which is resistant against mechanical breakdown; they are biologically inactive so they will not breakdown by soil microbes.

In most cases except for degradable polymers release of fertilizers will be happen by diffusion through polymer coat rather than through defects. In some other coated fertilizers like sulfur coatings there should be a flaw in coating to make release of fertilizer.

There are lots of examples for polymers which have been used in literatures as coating for fertilizers, some of them are as follow; dicyclopentadien[30], Urea and urethane based [31-36], epoxy based [37-39], polyvinylidene chloride-based latex[29] carboxyl-carrying ethylene polymers[40], biodegradable starch based[41], urea formaldehyde[42].

However, polymer coated fertilizers have some week points. About solvent-based coatings using large amount of organic solvents like toluene or xylene will lead to environmental concerns. These solvents are volatile and releasing them to environment makes some hazards for human health. Also, polymer coatings are more expensive than sulfur coatings; the process and equipments are also more complex than equipments used for other coatings.

2. 5. 2. Sulfur-polymer coated

One of most common coated fertilizers are the ones in which core fertilizer is covered by a layer of sulfur coating and a layer of polymer. The polymer layer can be primer or outer layer; means that sulfur layer in some researches has been the first layer and in some others the outer layer. Sulfur

Using coating is a suggested method to remove drawbacks of sulfur coated CRFs. One of these drawbacks is very fast release of fertilizer in first few days after application. The other one is brittleness of sulfur coatings which may lead to some fractures during handling or storage and losing the fertilizer into soil. Another problem is that sulfur coatings have a high surface tension with water and cannot provide enough wetting for a good diffusion [19, 29, 38, 21].

The most common method for applying the sulfur coating is spray. Molten sulfur compound will be sprayed over a pre-polymer coated fertilizer granule [38, 43].

2. 5. 3. Wax-polymer coated

There are lots of researches focusing on making controlled release fertilizers using Wax-polymer coatings. Wax layer has three major benefits; one is that they are applied over the polymer layer for decreasing the fracture probability of coating and the other one is for decreasing the amount of polymer and avoiding consuming more polymers to make the process cost effective. Also, they can eliminate imperfection of granules surface to make a good surface coating.

Most common waxes which have been used in state of the art is C30 alpha-olefin and paraffin. Other petroleum products like lubricants and bitumen or natural products like canola oil, soybean oil, coconut oil and palm oil, also have been used.

After melting the wax it will be applied by mixing with polymer coated fertilizer. Normally the polymer is thermoset to avoid any damages of polymer by the wax in its melting point. The wax normally should have drop melting point from 50 to 120°C. Wax is normally about 0. 2% to 10 % by weight of fertilizer [25, 38, 44, 45].

2. 5. 4. Filler- polymer coated

As mentioned before, despite lots of advantages of polymer coating to make slow release properties when such polymers are used as a sole coating material the ultimate product would be expensive as you have to consume large amount of polymer. Using mineral or organic fillers is one way to avoid using large amount of polymer. Also, in some researches fillers play the role of detackifier, to prevent adherence of coated granules to each other, and strengthening agent [46].

Fillers may be used either as a mixture with polymer to make a nano-composite polymer [47] or as a separate layer. The most common method is second one in which the filler will be added and mixed with polymer coated granules before drying the granules. Most common used fillers are some very fine(less than 20 microns) inert inorganic materials like clay, diatomaceous earth, bentonite, kaolin, gypsum powdered limestone, talc, barium sulfate. Some other fillers like waste cellulosic materials also have used as filler in combination with polymer.[47-51]

2. 6. Techniques coating application

According to studies have been done; encapsulation methods of fertilizers can be divided into three methods including in-situ, spray and mixing.

2. 6. 1. In situ

This method includes formation of fluid dispersion of the soluble fertilizer in a solvent and mixing the prepared solution with monomers of a polymer. Polymerization will happen and depend on the method; granules or particles of fertilizers will form.

Ni et al [52] have developed a double-coated urea fertilizer. For preparation of poly (N-vinyl-pyrrolidone) hydrogels containing urea (PCU), the monomer and a solution of urea in N-vinyl-pyrrolidone were mixed together. The polymerization was carried out at 65â-¦C for 3 h. The resulting samples were vacuum-dried, milled, screened and stored. After that first coating was dried sample and some amounts of urea were mixed with sodium alginate (SA) solution. Mixed solution was then added drop wise into 5% (w/w) $CaCl_2$ aqueous solution and stirred constantly. The drops immediately turned into granules (about 4mm in diameter) because the SA in the drop was crosslinked by Ca^{2+} at once. The granules were filtered and dried in oven at 70â-¦ C. Then the granules were added to ethylcellulose – ethanol solution. Multiple EC coatings were prepared by immersion of the previously coated granules into the Ethylcellulose (EC) solution repeatedly. Thus, EC-coated urea granules with different coating thickness were obtained.

Hanafi et al [53], have coated a compound fertilizer by polyvinyl chloride (PVC), polyacrylamide (PA), natural rubber (NR), and polylactic acid (PLA) using in situ method. For encapsulation of compound fertilizer with polyacrylamide the granules were added to the solution mixture of monomers. Then the polymerization reaction will start in existence of fertilizers. The thickness of the coating layer on the compound fertilizer granules, determined by SEM, gave PVC compound coated fertilizer the highest value of 3. 04 lm, and the lowest was obtained by PA (2. 04 μm). Variation in the characteristics of the polymers would be utilized in producing CR compound fertilizer that fit the requirements of growing plants.

Hudson et al [38] used epoxy to coat the fertilizer. In this research the urea granules were charged to a pan and warmed to 95°C. Then the hydrogenated tallaw amine, 2-amino ethyl peperazine and bisphenol A diglycidyl ether were mixed and were added to the granules; meanwhile polymerization happened and prepared mixture was agitated till the fertilizer granules dried.

2. 6. 2. Spray method

This method is most common method for coating the fertilizer granules in state of the art[. Usually, the solution of polymer in a suitable solvent is sprayed on the granule of fertilizer and then the granules are dried to remove the solvent through evaporation. The treatment is repeated as often as necessary until the desired coating percentage is reached.

Lan et al [54] have used Chitosan and poly(acrylic acid-co-acrylamide) as biodegradable polymers to coat the NPK fertilizer. The NPK was compound fertilizer granules with about 2 mm in diameter. It was placed in a rotary drum and then the Chitson powder which was dissolved in epoxy-aceton solution was sprayed over the fertilizer. After drying the coating , Chitson coated granules were added to a flask equipped with a mechanical mixer. Carbon tetracholoride, polyethylene glycoloctyl phenyl ether, sorbite anhydride monostearic acid ester, solution of acrylic acid acrylamide , N, N-methylenebisacrylamide and ammonium persulfate was slowly added to the flask. After mixing the coated granules were dried in oven. This product with good controlled-release and water-retention capacity, being degradable in soil and environment-friendly, could be especially useful in agricultural and horticultural applications.

Tomaszewska et al [55] have used spray technique for encapsulation of fertilizers. In order to improve the properties of coatings, the granules of previously coated fertilizer (wet method) were sprayed with a polymer solution or pure solvent (N, N dimethylformamide). Concentration of the polymer in solutions used for spraying was in the range of 13-17 wt%. Measurements of thickness, porosity of prepared coatings and microphotographic observation of the coatings were taken.

Ma et al [56] have developed a method for encapsulation of fertilizer with a self assembled coating. The fertilizer granules were heated in a rotary drum to 75°C for 10 minutes. Then the self assembling amphiphilic molecules (N, N-bisaminoethyl eleostearate) were sprayed over the fertilizer. After 20 minutes aliphatic isocyanates were sprayed over fertilizer. This process was repeated once again. The fertilizer kept for drying in the 75°C for 20 minutes.

Dai et al [57], have developed a controlled release fertilizer using a water soluble resin as a coating. The granular compound fertilizer was coated in fluidized bed.

Lan et al [58], prepared a double-coated slow-release NPK compound fertilizer with superabsorbent and water-retention properties (DSFSW), whose inner coating was chitosan (CTS), and the outer coating was crosslinked poly(acrylic acid)/diatomite-containing urea (PAADU). This prepared product not only has slow-release property but also could absorb a large amount of water and preserve the soil moisture at the same time. In addition, the outer coating (PAADU) could protect the inner coating (CTS) from mechanical damage. These were significant advantages over the normal slow release or controlled-release fertilizers, which generally have only a slow-release property. The results indicated that the DSFSW could be found an application in agriculture and horticulture, especially in drought-prone regions where the availability of water is insufficient. At first the outer coating containing urea diatomite (PAADU) was prepared. The NPK compound fertilizer granule was placed into a rotary drum, and the Chitosan powder was stuck on the granules by means of epoxy dissolved in acetone. The adhesive was applied by spraying at regular time intervals. The process was finished until compact and homogeneous coating formed on fertilizer granule. The coated granules were dried to a constant mass at room temperature for 6 h. Then the CTS-coated NPK compound fertilizer granules were obtained. CTS-coated NPK compound fertilizer granules were dipped in water and then were immediately placed on PAADU powder and shaken. In this manner, PAADU could adhere to the surface of CTS-coated NPK compound fertilizer and form the outer coating. The surface of the product was crosslinked by spraying methanol solution of epoxy chloropropane and then dried in a 70 °C oven to obtain the final product, i. e., the double-coated slow-release NPK compound fertilizer with superabsorbent and water-retention.

Hansen et al [36], encapsulate the granular fertilizer with the epoxy resin using spray method. In this research not coated fertilizer was placed in a rotating drum and pre heated to 250° F. A rapid drying solution of copolymers dicyclopentadiene and a modified vegetable oil were applied over fertilizer using spray in a thin stream of resin. Simultaneously hot air was passed through drum. Next monomers of second resin including a mixture of epoxidized soybean oil and polyester curing agent were applied over prepared granules. The solvent was a mixture of xylol and Cellosolve acetate.

Hansen et al [39] also have used the above mentioned method for encapsulation of fertilizer with polyurethane. First of all the preheated fertilizer was coated by a synthetic drying oil. After drying the coating for a few minutes fertilizer were dusted by clay. Then Urethane solution in xylene and Cellosolve acetate were applied using spray.

2. 6. 3. Simple mixing

In this method granules are simply mixed with the coating at its melting point or with a solution of polymer in a suitable solvent.

Tomaszewska et al [59] used this method for coating the granular NPK fertilizer with polysulfone (PSF), cellulose acetate (CA) and polyacrylonitrile

(PAN). The coating solutions were prepared by the dissolution of the solid polymer in adequate solvent. The NPK fertilizer was successively added to adequate polymer solution, and was covered by a thin layer of the solution. Subsequently, granules were dropped into water, where the gelation process takes place. The coated granules were removed from the precipitation bath and then dried to a constant mass. The multiple coatings were prepared by immersion of the single coated fertilizer into adequate polymer solution, then into water and drying.

Hon [47] has prepared the coated granules by mixing method. After melting the thermoplastic polymer by heating, the cellulosic additive has been added to melt resin. Then after allowing the temperature to drop, for avoiding the fertilizer damage, the granules or powder fertilizer has been mixed with the prepared mixture using a Brabender Mixer.

Markusch et al[60] just has mixed the fertilizer pellets with at first, a diluted polyol and then with a diluted isocyantae to make a polyurethane coating. Then the feretilizer were placed in oven for drying.

2. 7. Special equipment for application of polymer coating

Typical physical method for encapsulating fertilizers are spray coating, spray drying, pan coating, rotary disk atomization. Special equipments for these methods are rotary drum, pan or ribbon or paddle mixer, fluidized. Fluidized bed and rotary drums are the most important equipments [87, 88]

Polymers used as coating for CRFs

A broad range of polymers has been used in fertilizer coating. These polymers could be thermoset, thermoplastic or biodegradable.

Some of common thermoset polymers are urethane resin, epoxy resin, alkyd resin, unsaturated polyester resin, phenol resin, urea resin, melamine resin, phenol resin, silicon resin. Among them, urethane resin urethane is very common used.[36, 61]

Thermoplastic resins are not very common used in art because of some problems. As mentioned before a very preferable method of applying polymers is spraying the dissolved polymer over granules. Either some of thermoplastic resins are not soluble in a solvent or make a very viscose solution which is not suitable for spraying. Polyolefine is used in art for coating the fertilizer granules [47, 62].

Biopolymers, dispose in bioactive environments, degrade by the enzymatic action of microorganisms such as bacteria, fungi, and algae and their polymer chains may also be broken down by non enzymatic processes such as chemical hydrolysis. Non-biodegradable polymers are not environmental friendly. Due to environmental concerns there are some trends of replacing non-bio with bio degradable polymers as coating material from 1970s. But it should be mentioned that they are expensive yet and not very cost effective. Also, in production process durability of polymer should be adjusted with release time of fertilizer.

Among natural and synthetic biopolymers starch and cellulose based polymers, chitosan (a linear polysaccharide), poly lactic acid and poly(Îµcaprolactone) due to low cost and abundance are some of used biopolymers in fertilizer industry[41, 52, 58, 63-69]

2. 5. Coating thickness

Generally, polymer coatings are applied in a thickness which is suitable to make a desired controlled release property. Thickness could be related to characteristic of polymer and also it depends on existed porosity of polymer surface. If water vapor transmission rate of coating material is 0. 01 to 20, coating thickness would be 1 to 100 microns. Preferred coating thickness is 1 to 50 microns. Coating process could be repeated more than one layer to get desired nutrient release [49].

2. 6. Investigation of release behavior of CRFs

Release mechanism for different coatings is different. Thick encapsulated granules like sulfur coating will allow the nutrient to release when a flaw or rupture appears on the coating surface. In this case, rupture will happen because of permeation of water into coating and inside osmotic pressure. Also, biodegradable polymers will release nutrients while destroying by soil microbe's activity. Polymer coatings or combination of different coatings will happen by diffusion of water through wall's porosities. In this case release rate of can be controlled by the particle size of coated granules, thickness of coating and permeability of coating surface.

Also, altering the chemical composition of fertilizer core and the coating will change permeability of coating; means that even basic or acidic environment will change the permeability. In some researches when the coating has been starch-vinyl, increasing size of encapsulated granules has led to slowing down the nutrient release [70, 71].

There are some standard test methods for measurement of controlled release properties. According To European standard the standard release time of N during 24 h should be 15%

of total core nutrient. Also, release rate for 15 day should be 75% of total nutrients. Also American and Japanese standards say that the initial release shouldn’t be more than 40% of total nutrient.

According to European standards for measuring the release rate encapsulated fertilizer should be immersed in pure water at 25 °C (room temperature) in incubated state [72, 73]. For example Detrick et all[43] have investigated the release behavior of their product by immersion of 20 g of encapsulated granules for 8 h in water. After filtration of solid they dried the solid. Evaporation of water was done at 100 °C for 8 hours. Also, Ma et all [31] placed 14 g of granules in wire mesh holder into a jar with 300 ml water at 23 °C and agitated ir by an orbital shaker. Then, the adequate water was taken for elemental analysis.. Locquenghien et al [40] for investigation the slow release effect of fertilizer some amounts of fertilizer were continuously extracted with water. For this purpose the granules were arranged in layer in a cylindrical vessel field with water. Water was passed through this layer and its Nitrogen content was analyzed.

2. 8. Commercial CRFs in world and Malaysia

Urea-formaldehydes are oldest slow release products which were produced in 1936 and then were commercialized in 1970s. These products were known as Ureaform, Bluchip, Nitroform Methex and Nutralene. After that Tennessee Valley introduced sulfur coated urea technology in1960s. Polymer coated fertilizers were produced as early as 1970 in Japan. Most important commercialized polymer coated CRFs are Osmocote, Nutricote [74]

Osmocote CRFs are NPK granules coated by a thermoset copolymer of dicyclopentadiene and a glycerol ester (linseed oil) dissolved in an aliphatic hydrocarbon solvent. The Osmocote CRFs are normally used for ornamental horticulture production like greenhouses, nurseries , citrus , and strawberry production[75].

Nutricote prills are encapsulated by thermoplastic resins likeas polyolefins, polyvinylidene chloride. The process of Nuricote involves dissolving polymer in fast-drying

chlorinated hydrocarbon solvents and then applying the solution to a variety of nutrient substrates including urea, potassium sulfate, diammonium phosphate, ammonium nitrate and potassium chloride. Blendin the polymer with talc and ethylene-vinyl acetate has been done to obtain desired release rate[76] Sierra, Lesco and polyon are some other commercialaized CRFs in the world.

In Malaysia two brands named Greenfeed[77] and KAMILA[78] has developed slow release fertilizer. Greenfeed contains Zeolite which helps to release nutrients when it is in contact with soil. KAMILA is specially formulated for oil plantation industry.

2. 9. Tracing nano-technology features in fertilizer industry

Reviewing literature shows that researches which have used nano-technology features in fertilizer industry are very rare. The main benefits of nanoparticles in these researches are using them as reservoir of fertilizer or as filler [79, 80].

Solid nano-particles, have large surface areas and their reactivity is much more greater than that of micrometer size materials. Also, their surfaces and interfaces provide an active substrate for physical, chemical, and biological reactions [80].

Two published researches have done using nano-particles. One has used nano-clay as carrier of metal-urea complex; urea intercalated clay without any coating has been developed as slow release fertilizer[79]. In other one, a nanocomposite of nano particle, fertilizer and polymer has been granulated and developed as slow release fertilizer. The production method involves mixing monomers, adding nano particle, which could be nano clay, nano bentonite, nano kaolin, polymerization and then granulating the mixture. In this research nano particle just work as good and effective filler [81].

Making polymer-nano-particle composites is something common in industries. Lots of researches have been done in this area, but researches around using nano-particle as reservoir for fertilizer have been done rarely. For more study here, we will review the researches have been done.

2. 9. 1. Interc