Title: COMPOST BASED ON MINERAL FERTILISER

Abstract: The compost includes living and dead microorganisms together with a mineral substrate (such as rock phosphate) partly digested during a relatively dry, self-heated composting process. A fish hydrolysate nutrient and first inoculum including thermophiles is mixed with ground rock, which has been made lighter and more porous by addition of sawdust. The composting process is aerobic as a result of air blown through the composting mass. A second inoculum is mesophilic and persists until application. The dry product has a neutral pH.
TITLE  COMPOST BASED ON MINERAL FERTILISER

FIELD

This invention relates to a fertiliser; to a fertiliser based on a phosphate rock, and to improved methods for manufacturing fertilisers providing available phosphate and other nutrients.

BACKGROUND

Fertilising the soil is a way of increasing the ability of arable land to support the growth of farmed plants by overcoming shortages in one or more nutrients and/or trace elements; sometimes also modifying the soil pH or its physical properties. Historically, a wide range of inorganic fertilisers have been applied. They comprise a small range of major elements required for plant growth. In addition a range of minor elements, as well as a range of trace elements may be mixed with those fertilisers and a customised selection from those ranges for use in any given fertiliser application may be made on the basis of experience, prior soil tests, plant mineral analysis, or animal pathology reports from the land to be treated. An ideal fertiliser would be cost-effective, release specifically those nutrients that are required, and release the nutrients at a controlled rate so that for example they are not leached out of the application site and washed away, such as into a lake.

"Organic fertilisers" has at least two meanings; one is fertilisers including carbon-based materials such as manure, dung, litter, compost, or peat and another meaning is fertilisers free of harmful chemical or other contamination (such as free of artificially modified life forms) in accordance with the agreed definitions of "organic farming". There have been a number of problems with efficiently producing such fertilisers. These include production problems resulting from the bacterial contamination that is often carried into the plant with the raw materials used.

Phosphorus availability is a limiting factor, at least under New Zealand conditions. Rock phosphate is a mined material available in considerable quantities in deposits in some parts of the world, such as Egypt, Morocco, and the United States of America. The active composition is calcium phosphate (apatite) although a varying amount of fluoride and carbonate exists in practice. Because it is well-known that even finely ground phosphate rock is of little practical use due to the low solubility of the phosphate within, one commercial product is made by grinding the rock to perhaps 200-mesh size, then treating the rock with concentrated sulphuric acid (optionally also phosphoric acid) to make "superphosphate". Although much of the phosphate is made available to plants in that way, and aerial topdressing with superphosphate has been an important aspect of New Zealand agriculture for many years, the phosphate is released too easily from this product. A significant proportion is leached out and enters
waterways and lakes with consequent eutrophication. Much of the rest becomes locked into
the soil. The very low pH of that fertiliser often damages foliage and reduces the population of
beneficial soil micro-organisms.

Chitralekha R et al showed recently that on an allophane New Zealand soil, superphosphate
treatment gave a peak P solution concentration (availability) of 0.2 micrograms/ml by 15 days
but which dropped back to less than 0.12 thereafter. A biologically reacted phosphate fertiliser
gave P levels which rose gradually to 0.2 micrograms/ml by about 70 days, and which
continued to rise up to 120 days when tests stopped.

Naturally occurring soil micro-organisms (of which there is an almost infinite variety) are
capable of extracting the phosphorus from soil or minerals including phosphate rock, and
making it available to plants. For example see Rose (1957) N Z J Sci Tech (B) (38) 773- who
refers to earlier work on such micro-organisms back to the beginning of the 20th century. 12 of
25 soil isolates by Rose had a solvent action on rock phosphate. Thien & Myers, Soil Sci Soc.
Am J 56 814-818 (1992) showed that more active soil microbial activity resulted in heightened
release of phosphate, possibly owing to the release of organic acids (reviewed eg in Goenadi et
al Soil Sci Soc. Am J 64 927-932 (2002)). The latter paper describes use of a strain of
phosphate solubilising fungus, Aspergillus niger BCC F.194 for solubilising Moroccan phosphate
rock under laboratory conditions. Interestingly, citric-acid soluble phosphate rather than water-
soluble phosphate was produced by the fungus. The paper concluded that a process could treat
ground phosphate rock with liquid culture supernatant as an alternative to sulphuric acid; a
process that could be called "bioactivation".

Fertilisers have previously been developed by the inventors' group in which non-thermophilic
micro-organisms together with a nutrient source are mixed together with a mineral substrate
(phosphate rock) with the primary intention of increasing the bioavailability of phosphate
through the action of the added phosphate solubilising fungi on the rock after application. The
mixing action takes place shortly before application. These methods have been the focus of
earlier international applications PCT/NZ93/00076 WO9506623 and PCT/NZ94/00099.
WO9508521, the contents of which are incorporated herein by way of reference. These
specifications, like others which provide a "package" of phosphate rock with micro-organisms
for extracting the phosphorus once the fertiliser has been broadcast, do not teach a lengthy
factory "composting" process.

The inventors' group has previously experienced problems when using plant material or animal
by-products such as fish or marine material, manure or waste from meat and milk processing
plants for their range of nutrients. Anaerobic conditions resulted in foul smelling odours
during breakdown. Unintended contamination with micro-organisms pathogenic to animals or
humans can occur particularly if manure or civic sewage is included. Any contamination can
be a major health and safety concern to anyone coming in contact with the fertiliser. One
particular problem that has been experienced in commercial production is contamination by
Clostridium perfringens, a spore-forming anaerobe (widespread in the soil), some strains of which
cause enterotoxaemia and "pulpy kidney" in sheep.

The inventors have found in trials that aeration by intermittently turning piles of composting
mixture with a mechanical shovel was inadequate and expensive. The time required for the
composting process was prolonged, and resulted in odour problems due to the anaerobic
breakdown of the organic nutrient in parts. Contamination by pathogenic micro-organisms
occurred as a result of the incomplete composting. The mixing steps may have an adverse
effect by re-inoculating the entire pile with pathogenic micro-organisms each time the pile was
turned. Better aeration alone did not solve the problem.

Tsuru in US 6548288 describes a method for producing, in an aerated liquid process at a
moderately raised temperature, a "high density antagonistic microbe base" fertiliser designed to
improve the ecology of a soil under treatment. Many other patent specifications address
similar goals. A number of publications relating to composting employ a raised temperature in
order to minimise the content of potential pathogens.

DEFINITIONS

"Aerobic" as used herein refers to conditions sufficient for the growth of aerobic micro-
organisms (involving use of oxygen as electron acceptors, for example) while disadvantaging or
preventing the growth of facultative and especially obligate anaerobes. An empirical measure of
aerobic conditions is "at least 5% oxygen".

"Compost" as used herein refers to "a compound manure or combination" (OED) or "a
mixture for fertilising land; esp. a composition of various substances (as muck, mould, lime,
and stable manure) thoroughly mingled and decomposed, as in a compost heap. (Websters
(1913)). A definition from the waste treatment industry is "aerobic thermophilic stabilisation".

"Organic" as used herein refers to carbon chemistry; compounds including carbon of biological
origin, unless the term is used in relation to "organic foods" or "organic farming".

"Pathogenic micro-organism" as used herein refers to a micro-organism capable of causing or
producing disease in animals and/or humans, as well as in plants. Examples of relevance
include the faecal coliforms Escherichia coli, (some strains at least), Salmonella spp, faecal
streptococci, or other faecal contaminants, spore-forming Bacillus spp and anaerobic Clostridia,
or viruses. Faecal coliforms are dominant in some forms of waste such as pig manure or
chicken litter which may be used as a nutrient source in a composting process.
"Primary micro-organism" as used herein refers to any beneficial micro-organism such as bacteria, or fungi that have the ability to break down and/or absorb the initial mixture of nutrient source and mineral substrate. This group includes thermophilic species or strains.

"Secondary micro-organism" as used herein refers to any beneficial micro-organism such as bacteria or fungi, less able to withstand the temperature during the initial composting period and which may be added subsequently.

"Thermophilic micro-organism" as used herein refers to any heat-tolerant micro-organism; such as bacteria, yeasts, or fungi regardless of whether the heat tolerance is a necessity for metabolism and growth, or merely a capability. For purposes of this specification, the term is used for the set of micro-organisms metabolically active around or above 40 to 65 deg C.

OBJECT

It is an object of this invention to provide a combination fertiliser or compost having both a biological and a mineral fertiliser component, or at least to provide the public with a useful choice.

STATEMENT OF INVENTION

In a first broad aspect the invention provides a compost based on a mineral or rock rich in at least one selected element, wherein the compost includes (a) the rock, reduced to a fine particle size and at least partially digested, (b) a proportion of the at least one selected element converted by an aerobic composting process into a biologically available form, (c) at least some micro-organisms or remains thereof in the form of organic matter; the compost having a low water content.

In a related aspect the invention provides a compost based on a phosphate rock, wherein the rock has been reduced to a fine particle size and a proportion of the phosphate has been converted into a form available to plants (the remainder being potentially available at a time after application) by means of a controlled aerobic composting process in which added micro-organisms, supported by added nutrients, extract and make biologically available an amount of the phosphate from the reduced rock; at least some of which micro-organisms or remains thereof in the form of organic matter persist in the compost as organic matter; the composition having an about neutral pH and a low water content.

Preferably the compost is capable of continuing to make supplies of the at least one selected element available to plants after an application, as a result of continued activity of micro-organisms upon the reduced rock.

Preferably the mixture is made by mixing together a nutrient source, at least one primary
micro-organism, a porous material, and a mineral substrate (the reduced rock).

Preferably the nutrient source is a fish hydrolysate.

Preferably the fine particle size is defined as "over 90% of a sample passes through a 1 mm mesh screen", although the duration of continued release of the at least one selected element after application of the compost may be extended by use of larger particle sizes.

In a first related aspect the micro-organisms include one or more types selected from a mesophilic group including some capability to extract the selected element from the reduced rock so that the compost includes means to continue to release the element after application.

In a second related aspect the micro-organisms include one or more types selected from a thermophilic group.

In a third related aspect the micro-organisms are obtained from soil samples.

In a fourth related aspect the micro-organisms are obtained from previous batches of compost.

Preferably the compost has a minimised amount of potential animal pathogens.

In a second broad aspect the compost includes up to about 3% by weight of available phosphate, up to about 5.5% of organic matter, and up to about 3% by weight of available nitrogen, and a low water content of between 5 and 10% by weight, so that the mixture has a friable sand-like structure.

In a first related aspect the fertiliser composition further includes a customised variety of added minor and trace elements, held within the compost, so that the needs of a particular customer may be satisfied.

In a second related aspect, a plurality of seeds of a plant species, and a species of bacteria together capable of fixing nitrogen is mixed with the compost, so that the compost provides a soil with a sustainable nitrogen fixing capacity. For example, *Rhizobium* spp bacteria may be included together with clover (*Trifolium* spp) seeds.

In a third broad aspect, the invention provides a method for making a compost based on a rock rich in at least one selected element, *wherein* the method includes the steps of reducing the rock to a specified particle size, mixing a supply of nutrients with the rock in order to create a mixture, mixing a first inoculum including a first set of selected aerobic micro-organisms with the mixture, holding the mixture in a container for a period of time, under aerobic conditions, until an evolution of heat has slowed and the mixture has cooled below about 40 deg C, optionally adding a second inoculum including a second set of selected
aerobic micro-organisms into the mixture, holding the mixture for a period of time, under aerobic conditions, until the second inoculum has become distributed through the mass and acted upon the rock, and supplying the resulting compost to a customer.

Preferably the first set of added micro-organisms includes one or more types selected from the following thermophilic group: actinomycetes including *Streptomyces*, fungi including *Zygomycetes*, phosphate- and other mineral-fixing bacteria including *Thiobacillus*, selected archaeabacteria, autotrophic bacteria including *Glomus tenuis*, aerobic composting bacteria including *Theobacillus, Alkaligenes, Azotobacter*, and *Pseudomonas*, acidophiles and lactic-acid bacteria.

Preferably the second set of added micro-organisms include one or more types selected from the following mesophilic group: *Actinomycetes* spp, fungi including *Aspergillus niger, Penicillium* spp, *Trichoderma viride, Gigaspora margarita*, vesicular-arbuscular (V-A) mycorrhizae such as *Ectomycorrhiza*, and bacteria including *Rhizobium, and Pseudomonas* spp.

Preferably the mixture has a low water content of less than 10% by weight, so that the mixture has a friable sand-like structure.

In a fourth broad aspect the invention provides a method for making a low-pathogen compost based on a mineral rock and added nutrients, wherein the mixture is permitted to reach a temperature of at least 50 deg C for at least a period of several days, so that micro-organisms not capable of thriving at that temperature are preferentially eliminated and so that the processed mixture contains a minimised proportion of potential animal pathogens.

In a related aspect the invention provides a container for holding a compost during a composting process, wherein the container is thermally insulated and includes means for aerating the compost by introduction of air from an air distribution means so that an aerobic environment is provided and so that self-heating is encouraged in order that a risk of holding potential pathogens is reduced.

In a first related aspect this invention provides a method for the production of a fertilising composition or compost, in which the temperature of the mixture during composting reaches 55°C or above and the moisture content is less than 10% by weight so that the mixture retains air spaces around particles and may be aerated.

In a second related aspect this invention provides a method for the production of a compost in which an added porous material is capable of being broken down by the at least one primary micro-organism during the period of time.

A preferred porous material is sawdust, and preferably the amount of the porous material
added is about one part sawdust to eighteen parts by weight of mineral substrate.

PREFERRED EMBODIMENT

Further aspects of the present invention will become apparent from the following description which is given by way of example only and with reference to the accompanying drawings.

DRAWINGS

Fig 1: is a diagram showing a composting container in cross-section.

Fig 2: is a graph 200 of temperature against time for an example composting process. 201, the horizontal axis, is in days and 202 - the vertical axis - is in degrees Celsius.

Surprisingly, it has been found that a "composting" process can be applied to digestion of a rock substrate, instead of (as usual) to the rotting of plant material employing bacterial and fungal action over a period of time (about one month) in order to create a relatively slow-release fertiliser presenting the mineral and organic constituents in a form readily available to plants in soil. The material produced by the invention comprises a free-flowing powdery or sandy material of 5% to 10% water content, a variety of dead or living micro-organisms and some secretions, at a pH of about 7 to 7.2 (sometimes pH 6.5 to 7.5, depending on the rock used). The micro-organisms have already begun to solubilise or digest the phosphate rock while being supported by a community of other micro-organisms that are converting the nutrients into cellular material. This composting process is closely controlled in the factory.

Aerobic and nearly dry conditions are deliberately maintained within a thermally insulated space, the temperature is allowed to rise and then fall during a period of significant microbial activity, and the material being composted is inoculated on at least one occasion with selected micro-organisms, some of which stay alive and enter the soil to be fertilised. The process may replace the acid treatment involved in manufacture of superphosphate fertiliser.

PHYSICAL CONTAINMENT

The inventors found that careful attention to the containment of the composting material was needed. In order to provide hot, aerobic composting conditions for bulk amounts of composition, a bin is constructed preferably from concrete (as shown in cross-sectional view in Fig 1) in a size capable of accepting a front-end loader or similar machinery. A concrete bin with walls 101 and floor 110, is shown in cross-section, holding a composting composition 100. Preferred dimensions are about 18 metres long, 10 metres wide and 2 metres high. Deeper bins would press down on and compact the deeper layers. Shallower bins do not heat as well,
and use up relatively more valuable factory floor space. Heat produced is retained with thermal insulation (such as polystyrene foam pads 102, 103) within the walls and floor of the bin, a cover 112, and preferably can be supplemented such as by buried heating means especially at corners (see pipes 105, 109) because the composition in corners may otherwise not reach an intended temperature. The array of rods 111 may be taken to represent an "under-floor heating" installation option, or may simply comprise a section through steel reinforcing mesh (which could be heated by connection to a high-current, low-voltage source of electricity). The required aerobic conditions are met, in this example, by pumping air through the composition 100. In general an air inter-outlet spacing of about 1 metre is found to be sufficient, especially with a modification to the mixture to be composted providing greater porosity (see below). The air may be heated or cooled and/or humidified as required. Thermal, oxygen, and humidity sensors are not shown, but close attention to process control is desirable.

Referring to Fig 1 in detail, two physical aeration methods are shown. To the left of the dotted line A-A, the first way to aerate the composition 100 is from suspended, perforated air pipes 107 (suspended perhaps from hook 108) is shown. A second way is shown to the right side of the dotted line A-A. Pipes 109 within the floor supply air to the composition through a matrix of holes 104. In both cases, air should pass through the entire mass of the composition 100 rather than forming open channels. Use of large-bore pipes, reasonable pressure, and small apertures makes the distribution system insensitive to variations of air resistance at any individual aperture. In the currently preferred process, the aerated composition is left to stand undisturbed for about a month until finally being removed for packaging and sale. No remixing or turning over treatment occurs prior to completion. See below under "Aeration".

During composting, there may be considerable growth of fungal hyphae within the composition.

It is relevant to state here that the preferred composition is always visually dry during composting. Less than 10% water by weight, more preferably less than 8% is used so that the physical appearance of the composition is a free-flowing powdery or sandy material. After a time, growth of fungal hyphae through the mass tends to create friable lumps. It has been a surprising discovery by the inventors that the desired composting reaction proceeds best under those dry conditions. This may reflect the predominance of fungi in the process, and also facilitates aerobic conditions. Workers should guard against starting a batch with damp phosphate rock or watery nutrient mixtures because these may cause the water content to exceed 10%, raising the risk of anaerobic microbial activity which is inefficient, smelly, wasteful of nitrogen (much of which is lost as ammonia) and promotes the survival of some pathogens. If the material cannot be dried before use, some dried bentonite (a clay) or the like may be added to take up some moisture.
PHOSPHATE or other ROCK:

The preferred mineral substrate used is phosphate rock, a widely used commodity available through international trade. A hard North African rock, not a "reactive phosphate rock" includes about 15% P. This is suitable. The material is ground to a fine particle size typically such that 90% will pass through a 1 mm screen although use of a greater proportion of larger particles will result in a longer period of release after application. Phosphorus and nitrogen are the macro-elements most in demand as fertilisers. Other suitable mineral substrates, (though not phosphate-rich) include: limestone, dolomite, zeolite, bentonite, serpentine, and volcanic rock.

MINOR AND TRACE ELEMENTS

Standard inorganic fertilisers usually offer a limited range of elements (selected from nitrogen, phosphorus, potassium, magnesium, calcium, and sulphur). Standard organic fertilisers include urea (for nitrogen), blood and bone, chicken litter and the like for a wider spectrum of organic supplements. The present invention permits a wider range of inorganic elements to be supplied in slow-release form, bound as chelates such as with amino acids or together with organic compounds within living or dead micro-organisms. The organic material significantly improves the Cation Exchange Capacity (CEC) of a soil, over time. The preferred nutrients used in this invention inherently contain some minor and trace elements and others can be added to the fertiliser of the invention, as is known in the art, in order to compensate for suspected or proven shortages in the soil to be fertilised. Trace elements may be added as required to the mineral substrate and/or the nutrient source in the form of inorganic compounds such as sulphates, or as organic chelates available for all trade elements. The set of "trace elements" (the need for which is indicated by soil, plant, or and animal assays) includes boron, copper, cobalt, manganese, iodine, magnesium, molybdenum, zinc, and selenium.

ADDED NUTRIENTS:

A source of microbial nutrients is used during composting because the rock phosphates as supplied lack sufficient organic and nitrogenous materials, minor and trace elements for microbial metabolic processes to occur at the desired rates. An advantage is that most of the added nutrients are retained in the final mixed product as bio-available materials; nitrogen, for example is within living or dead micro-organisms or their secretions. Hence some of the original microbial nutrients become plant nutrients after application to the soil. Also, the nutrients are fuel for the self-heating process that eliminates pathogens.

The inventors prefer a nitrogen-rich nutrient source, namely fishing industry by-products known as offal, fish hydrolysate or fish silage (guts, fins, heads and the like, non-food species, deteriorated catch, all of which is ordinarily considered inedible waste). This readily and
cheaply available rich nutrient source otherwise presents a disposal problem. An advantage of fish is that being cold-blooded, their by-products are not likely to be carry pathogenic micro-organisms dangerous to people or farm animals, whereas animal-derived materials can be expected to include pathogenic micro-organisms that might be transferred to humans or other animals through contact with fertiliser made with such nutrients. Although preliminary sterilisation could be carried out, it may not be cost-effective.

The inventors prefer that the fish offal has a reasonably high solids content. They acidify ground, wet fish offal in a mixing vat in order to reach a pH of less than 3.7, preferably about 3.0 to 3.3 which will retard bacterial degradation although autolytic degradation by stomach enzymes may continue at this pH. A pH of less than 2 gives longer preservation. This requires addition of about 1 to 1.5% of concentrated sulphuric acid, its equivalent of hydrochloric acid, or a mixture of formic and inorganic acid. The resulting slurry is herein termed "the nutrient".

MICROBIOLOGY

The first inoculation of selected micro-organisms into the compost initiates the composting process at a desired rate and with an intended mixed population of largely thermophilic and rock-attacking micro-organisms. The composting process will typically take four weeks to produce the compost/fertiliser. As is common in composting, there is a substantial evolution of heat during nutrient breakdown within this process (see Fig 2). In the preferred method the heat is desired and is not normally dissipated. Thermophilic organisms are preferred as the first inoculate, to maintain microbial activity and the intended population during the high temperature phase. As can be seen from Fig 2, the mass typically remains at 55 degrees C or above for about 10 days. A temperature of at least 50 deg C is preferred in order to (a) speed the composting process, which even with this temperature profile still lasts for about a month, and (b) to help to eliminate undesired pathogenic organisms. The inventors have identified 50 to 55 deg Celsius as an approximate composting temperature at or above which few pathogenic micro-organisms will survive the composting process. Within limits, a higher temperature is more effective. Testing of the microbiological content of the compost showed that pathogens were destroyed in the fertilising composition within 24 hours at 60 deg C or within 1 hour at 70 deg C. However, the beneficial micro-organisms are also destroyed above 90 deg C.

Another advantage of thermophilic micro-organisms in this process is that their activity is much reduced after introduction into soils, where they will be at a competitive disadvantage as compared to ordinary (mesothermic) soil bacteria).

It must be realised that some pathogenic micro-organisms may sporulate in adverse conditions. Also, it must be realised that persons receiving immune suppression therapy or who otherwise have a compromised immune system will be liable to infection by many of the fungi used in
this invention.

Thermophilic bacteria and fungi occur in many soil sample isolates, though are more likely to be found in soil isolates from hot springs (or other volcanically heated ground). Some of those are known as the archaeabacteria. Some soil fungi are inherently thermophilic. Inoculategenerated from past batches of the same process, or isolated from the raw phosphate rock before use are also suitable sources. For (a non-limiting) example, a mixture of primary micro-organisms may be selected from the group of: actinomycetes such as *Streptomyces*, fungi such as *Zygomyces*, phosphate- and other mineral-fixing bacteria such as *Thiobacillus* and selected archaeabacteria, autotrophic bacteria such as *Glomus tenuis*, aerobic composting thermophilic bacteria such as *Theobacillus*, *Alkaligenes*, *Azotobacter*, *Pseudomonas*, *acidophiles*, lactic-acid bacteria and the like. That list is given by way of example only: a range of other aerobic micro-organisms could also be used separately or together as would be appreciated by a skilled addressee. Indeed, an effective inoculate could be obtained and used without identifying the species within. Micro-organisms are known to exchange genetic material in nature.

Prior art composting techniques (using plant material) have avoided temperatures of much over 40 deg C because higher temperatures tend to destroy the non-thermophilic organisms responsible for the composting action and would result in an aborted processing cycle.

The inventors prefer to inoculate the fertiliser with at least one secondary micro-organism after the initial peak of composting activity and after the temperature of the fertiliser had dropped to below about 50 deg C. Additional thermophilic micro-organisms (such as from the class *Zygomyces*) may optionally be added in order to consume the nutrients released by the breakdown of the nutrient source and mineral substrate. Additional nitrogen or phosphate-fixing micro-organisms may also be added to fix nutrients released by the composting process. This allows further breakdown of the nutrient and mineral substrates by selected micro-organisms which would have been destroyed by the high temperatures during the earlier phase of composting. At least some of the secondary group will be carried into the soil treated by the final composted fertiliser where, in addition to further decomposition of the phosphate rock by added micro-organisms, modification of the existing microbial ecology (such as the suppression of plant pathogens) may be desired.

Once the composting process slows and the temperature drops below 40°C, secondary micro-organisms may be added in a similar manner in order to complete the composting process and adsorb the nutrients released during composting. Such nutrients can then be gradually released to the plants once the fertiliser has been applied to the soil. Optionally, other lithotrophic and/or chemoautotrophic / lithotrophic micro-organisms are added in order to fix nitrogen, sulphur and iron and to aid in the utilisation of these materials once the fertiliser is applied to

Additional micro-organisms may also be added during the final stage of the composting process (at 206) in order to suppress plant pathogens once the fertiliser applied to the soil. It will be appreciated that the ecological microbiology of soil is complex. (We have not considered protozoa, nor multicellular life such as nematodes or annelid worms in this specification). Fertilisers including micro-organisms provide a careful gardener or farmer with a good opportunity to modify the existing ecology of a soil both by altering substrates and also by inoculating relatively large numbers of selected microbial species.

(The above list of mesophilic organisms was given by way of non-limiting example. The inventors have contributed a soil treatment composition itself worth spreading for intrinsic fertiliser-type benefits that is also compatible with specific soil ecology modifiers such as (for example) US 6387146 Protzmann - a mycorrhizal fungus useful in symbiotic relationships, and US 6074451 Goda, a *Pseudomonas* species for controlling the common scab of potato).

One useful source of secondary micro-organisms comprises a proportion of a previous fertilising composition, used as a starter culture to inoculate each new fertilising composition. The composition of the fertilising composition as sold is monitored by semiquantitative (serial dilution plates) microbiology in case undesired micro-organisms should appear. The manufacturers would also store reserve supplies of approved inoculates.

**AERATION**

An aerobic composting environment is highly desired. The growth of beneficial micro-organisms is favoured, efficient composting occurs without odours, and anaerobic pathogens such as many *Clostridia* spp are strongly discouraged. Two improvements are used; preferably together, on the substantially dry mixture during the composting process. The first is to provide forced-air ventilation for example as previously described with reference to Fig 1. The flow rate and pressure should be sufficient to provide a gentle current of air. The air may be heated in order to speed the onset of the composting process, and to help ensure that the entire mass, even in corners and around air inlets, reaches at least a desired temperature (such as 55 deg C). Temperature may be monitored by a thermometer built into a long probe and directed manually into the heap, or by use of an automated monitoring system. To date we have not used a probe to sense anaerobic areas directly, although an oxygen electrode could be built into a probe. A smell of ammonia is another sign of anaerobic fermentation. We find that aeration through pipes is cheaper and far better for providing an aerobic environment than
previous methods which involved turning the piles of fertiliser occasionally with a mechanical shovel.

Inoculates may be introduced via the aeration system and dispersed under positive pressure into the fertilising composition, or they may be dispensed by hand using a backpack sprayer and a lance. The moisture content of the composition can be monitored and changed if necessary by controllably humidifying the incoming air.

The second improvement related to aeration is the use of "porosity-enhancing" additives that physically modify the density and structure of the composition. Finer ground rock restricts the ability of air to diffuse through the composition, significantly so for the preferred fineness grade. A preferred porosity enhancing additive is dry sawdust, preferably taken from un-treated wood in order to avoid introduction of toxic chemicals into the food chain. This material immediately serves to lighten and to break up the composition, but later the sawdust (comprised of cellulose, lignin, and xylans) becomes digested by fungal action and is substantially invisible in a final product. The digested sawdust will leave voids within the undisturbed, dry composition.

One preferred proportion of sawdust is about one part of sawdust to 18 parts of mineral (both by weight). Other proportions may be used depending on specific conditions and on the nature of the composition and of the sawdust or analogous substance. Any sawdust is an advantage. Too much may distort the balance of micro-organisms in the final product or lower the rated concentration of available phosphorus. Some sawdusts or barks may contain natural substances deleterious to the desired microbial ecology.

**EXAMPLE 1**

Figure 2 illustrates a temperature: time curve for a typical composting process as used in the present invention for the production of a fertilising composition, including a high-temperature composting sequence and aerobic conditions. The conditions were as follows:

A quantity (900 kg) of dry rock phosphate was ground or otherwise broken down to a desired particle size and mixed with about 50 kg of untreated sawdust (a ratio of about one part sawdust to 18 parts of rock phosphate), in order to provide the mineral substrate.

50 litres of liquid fish based by-product, prepared as previously described was used as a nutrient. The acidic nutrient becomes neutralised on mixing with the ground rock. Approximately 10 litres of primary micro-organism inoculant (as previously described) was dripped onto the rock/nutrient mixture as it passed along a conveyer. That mixture was then mixed well with the porosity modifier (sawdust) and the resulting composition was placed into insulated concrete fertiliser bins. (See point 203 on the graph of Fig 2). Note that the water
content is about five to ten per cent, which is unusually low for a composting process. During composting and afterwards, the product is a flowable powdery material, compatible with normal fertiliser spreading machinery and compatible with diffusion of air through the mixture.

The composting process will typically take four weeks to produce the fertilising composition. When the composition drops to 40 deg C or below, or at other times, additional thermophilic micro-organisms may be added as previously described in this section. Optionally, yet further lithotrophic and/or chemolithotrophic / lithotrophic micro-organisms are added in order to fix nitrogen, sulphur and iron and to aid in the utilisation of these materials once the fertiliser is applied to the soil. Additional mesophilic micro-organisms may also be added in order to suppress plant pathogens once the fertiliser applied to the soil. The neutral, dry nature of the composted mineral fertiliser is compatible with such additions.

The composition of the product according to the invention is typically (by weight): 

Water 5-10%, Total Phosphorus 11-14%, Plant-available Phosphorus about 3%, Organic material up to about 6%, Nitrogen up to about 3%, Calcium about 35%, pH 6.5 - 7.2. All the phosphorus will be released over about one year after application, assuming healthy soil. A flowable brown powdery to sandy material, compatible with normal fertiliser spreading machinery. Tendency to form loosely adherent lumps if stored, owing to continual fungal activity. (Shelf life has not been tested). These values depend on the original rock as well as the process and the balance of organisms present, as will be realised by one skilled in the art. The mass or organic material appears to have increased slightly over that originally included, suggesting some carbon fixation has occurred.

VARIATIONS

The greatest variability in relation to use of this invention relates to the very wide selections and balanced groupings of micro-biological forms that may be added in varying quantities to the composition, during or after the composting process. Some of these may be genetically engineered organisms, such as to provide desired thermophilic characteristics in addition to a gene product active in a desired aspect of fertiliser bio-availability. Some will be selected or modified in order to modify the soil ecology of a target soil for a particular purpose. On the other hand perfectly good organisms may appear within any soil isolate, as a result of gene swapping occurring naturally between existing strains of micro-organisms. Over-reliance on species identification may be a fallacy.

The neutral pH of the dry product permits addition of materials such as living plant seeds and clover seeds with Rhizobium spp (an example of a symbiotic group providing long-term self-sustainable nitrogen fixation). The dry state of the composition does not stimulate seed germi-
nation and the neutral pH does not reduce viability of the seeds.

In relation to nutrients, in some situations there may be a requirement to partially or completely substitute other aquatic-derived material such as seaweed, or other animal by-products such as manure, waste from meat and/or milk processing plants, used litter, waste food, waste from animal processing plants or civic sewage, for the preferred fish offal/hydrolysate.

Materials other than sawdust may be added in order to facilitate aeration, such as chopped straw, finely chopped cardboard, waste paper, wood chips, bark, and wood shavings.

Mineral materials that may be used instead of, in addition to, or as well as phosphate rock includes feldspar (for potassium), bentonite (for water absorption), zeolites (for chelation), dolomite, lime, granite, serpentine, or volcanic rocks.

An aeration process involving mechanical agitation of the material (see for example PCT/FR01/02402 Chenu) may be used but the elongated shapes of the storage bins involved may prevent the evolution of sufficient heat and the infrequent aeration may lead to anaerobic fermentation.

Details of the composting process as described herein are dependent on the volume of fertiliser manufactured, the type, concentration, and pH of the nutrient source, and the nature, type, and particle size of the mineral substrate, the composition and concentration of the micro-organisms, the thermal insulation efficiency (R value) of the bins and any extra heating, as well as the ambient temperature, efficiency of oxygenation, moisture content and so forth, as will be realised by a person skilled in the art.

**INDUSTRIAL APPLICABILITY and ADVANTAGES**

1. The procedure has a competitive cost, in production volumes. For example, a price "on the ground" per kg is expected to be about NZD 2.30 whereas conventional superphosphate is about NZD 2.00 - 2.15 per kg yet has less available phosphate in the long term, no organic materials or nitrogen, and some disadvantages. The product is a "high-test fertiliser".

2. The product as sold includes soluble phosphates, and micro-organisms adapted to further solubilise and distribute phosphate from the phosphate rock substrate even after application; the release occurring relatively steadily over an extended period typically one year, assuming a healthy soil with microbial activity.

3. The product as sold is a flowable powder or granular brown material, and typically the pH is 7 to 7.2 - perhaps 6.5 to 7.5 with some rock types.

4. Although the product as sold includes micro-organisms and has been through a composting
type procedure, the proportion of potentially dangerous (pathogenic) organisms within the
product has been deliberately minimised by (a) direct effects of the high temperature used,
(b) competition with thermophilic organisms during the high temperature phase, and (c)
effective aeration during the composting type procedure.

5. The product as sold includes a soil inoculum capable of modifying the ecology of a target
soil including for example mycorrhizae. (If this was not desired the product may be
sterilised before use).

6. The product as sold includes minor and/or trace elements; the release of which occurs
relatively steadily over an extended period from the cells or remains of the micro-organisms
included.

Finally, it will be understood that the scope of this invention as described and/or illustrated
herein is not limited to the specified embodiments. Those of skill will appreciate that various
modifications, additions, known equivalents, and substitutions are possible without departing
from the scope and spirit of the invention as set forth in the following claims.
CLAIMS

1. A compost based on a mineral or rock rich in at least one selected element, characterised in that the compost includes (a) the rock, reduced to a fine particle size and at least partially digested, (b) a proportion of the at least one selected element converted by an aerobic process into a biologically available form, (c) at least some micro-organisms or remains thereof in the form of organic matter; the compost having a low water content.

2. A compost based on a phosphate rock, characterised in that the rock has been reduced to a fine particle size and a proportion of the phosphate has been converted into a form available to plants (the remainder being potentially available at a time after application) by means of a controlled aerobic composting process in which added micro-organisms, supported by added nutrients, extract and make biologically available an amount of the phosphate from the reduced rock; at least some of which micro-organisms or remains thereof in the form of organic matter persist in the compost as organic matter; the composition having an about neutral pH and a low water content.

3. A compost as claimed in claim 2, characterised in that the compost includes up to about about 3% by weight of available phosphate, up to about 5% organic matter, up to about 3% by weight of available nitrogen, and a low water content of between 5 and 10% by weight, so that the mixture has a friable sand-like structure.

4. A compost as claimed in claim 3, characterised in that the compost is capable of continuing to release the at least one selected element after an application, as a result of continued activity of micro-organisms upon the reduced rock.

5. A compost as claimed in claim 4, characterised in that the duration of continued release of the at least one selected element after application may be in part determined by control of the particle size of the rock.

6. A compost as claimed in claim 4, further characterised in that a plurality of seeds of a plant species, and a species of bacteria together capable of fixing nitrogen are included with the compost, so that after application the compost also provides an environment with a sustainable nitrogen fixing capacity.

7. A compost as claimed in claim 4 characterised in that the fertiliser composition further includes a customised variety of added minor and trace elements, held within the compost, so that the needs of a particular customer may be satisfied.

8. A container for holding a compost as claimed in claim 1 during a composting process, characterised in that the container is thermally insulated and includes means for aerating
the compost by introduction of air from an air distribution means so that an aerobic environment is provided and so that self-heating is encouraged in order that a risk of holding potential pathogens is reduced.

9. A compost as claimed in claim 2 characterised in that the temperature of the compost was raised to a temperature of at least 50 deg C for at least a temperature-related minimum time, so that mesophilic micro-organisms are preferentially eliminated and so that the processed mixture contains a minimised proportion of potential animal pathogens.

10. A method for making a compost based on a rock rich in at least one selected element, characterised in that the method includes the steps of

(a) reducing the rock to a specified particle size,
(b) mixing a supply of nutrients with the rock in order to create a mixture,
(c) mixing a first inoculum including a first set of selected aerobic micro-organisms with the mixture,
(d) holding the mixture in a container for a period of time, under aerobic conditions, until an evolution of heat has slowed and the mixture has cooled below about 40 deg C,
(e) optionally adding a second inoculum including a second set of selected aerobic micro-organisms into the mixture,
(f) holding the mixture for a period of time, under aerobic conditions, until the second inoculum has become distributed through the mass and acted upon the rock, and
(g) supply the resulting compost to a customer.

11. A compost as claimed in claim 10, characterised in that the first set of added micro-organisms includes one or more types selected from the following thermophilic group: actinomycetes including *Streptomyces*, fungi including *Zygomycetes*, phosphate- and other mineral-fixing bacteria including *Thiobacillus*, selected archaebacteria, autotrophic bacteria including *Glomus tenue*, aerobic composting bacteria including *Theobacillus, Alkaligenes, Azotobacter, and Pseudomonas*, acidophiles and lactic-acid bacteria.

12. A compost as claimed in claim 10, characterised in that the second set of added micro-organisms include one or more types selected from the following mesophilic group: *Actinomycetes* spp, fungi including *Aspergillus niger, Penicillium spp, Trichoderma viride, Gignaspora margarita*, vesicular-arbuscular (V-A) mycorrhizae such as *Ectomycorrhiza*, and bacteria including *Rhizobium, and Pseudomonas* spp.
13. A method as claimed in claim 10 *characterised in that* a proportion of a pore-forming material is mixed with the mixture, so that the mixture is more easily aerated by a forced flow of air through the mixture.

14. A method as claimed in claim 13 *characterised in that* the pore-forming material is capable of being digested by micro-organisms included within the mixture.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.: C05F 1/00, 1/02; C05G 1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

SEE ELECTRONIC DATA BASES BELOW

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

STN Files CABA, WPIDS: key words compost, phosphate rock, mineral, ground, dust and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>GB 488639 B (WELLESLEY HOLDINGS LTD), 11 July 1938. See whole document.</td>
<td>1-14</td>
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</table>

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 19 January 2004

Date of mailing of the international search report 23 JAN 2004

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Form PCT/ISA/210 (second sheet) (July 1998)
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<td>M. MISHRA et al., &quot;Composting Rock Phosphate&quot; [online], (retrieved from internet 20/01/04), Internet Archive listing, URL: <a href="http://web.archive.org/web/19980201132226/http://fadr.msu.ru/rodale/agsieve/txt/vol2/2/art1.html">http://web.archive.org/web/19980201132226/http://fadr.msu.ru/rodale/agsieve/txt/vol2/2/art1.html</a>, entry date 01/02/98. See whole document.</td>
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<td>GB 1452973 B (J. KREMER-HOLTGEN), 20 October 1976. See whole document.</td>
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INTERNATIONAL SEARCH REPORT

Box I  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. [X] Claims Nos:  **1 to 14 (all in part)**
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
   See supplemental sheet.

3. [ ] Claims Nos:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:  

**Remark on Protest**

[ ] The additional search fees were accompanied by the applicant’s protest.

[ ] No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(1)) (July 1998)
Continuation of Box No: Box 1.2

The scope of the present claims could not be economically searched. Accordingly in order to adequately cover the matter of the preferred embodiments particular features were used to restrict the size of the answer set. These included the restriction of the mineral element to rock phosphate, restriction of the answers to methods in which the composting step is carried out at a "low" moisture level (initial search results indicated that other processes used higher levels of moisture during the composting, but post-treatment resulted in a compost having low water content), and restriction of the answers to those in which a fish product was used as a nutrient source. Accordingly this report cannot be considered an exhaustive search of the prior art relating to this invention.

Note that the apparatus of Claim 8 has not been specifically searched. Thermally insulated composting apparatus with means for providing aeration of the contents are well known in the art. The search has been limited to the use of the apparatus with composts incorporating the features noted above.
This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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END OF ANNEX