Capacity Building for Stakeholders in the Fertilizers Industry on Blends Formulations

**Fertilizer Producers and Suppliers Association of Nigeria
(FEPSAN)**

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for

F E P S A N

**Fertilizer Producers and Suppliers Association of Nigeria
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FOREWORD

Fertilizers of inorganic and organic origins have become one of the most essential inputs for any successful agricultural crop production venture. This fact has been widely accepted by all stakeholders in the agricultural industry. Unfortunately, some operators of these essential input do not appear to have the requisite knowledge needed to ensure that the production of these inputs with the minimum acceptable allowance of errors.

Fertilizers must have good physical properties for storage, transportation and handling and meet the stated value of the nutrients labeled on the container. Stemming from the fact that disparity has been common between the label value and what the fertilizer contains, there is need to certify the claim of fertilizer manufacturer/contractor to safe guard the farmers and the environment, who are the ultimate victims of poor-quality fertilizer.

It is in this spirit, the Fertilizer Producers and Suppliers Association of Nigeria (FEPSAN) has engaged a Consultant with some experience on fertilizers to enhance the knowledge of stakeholders in the Nigerian fertilizer industry, on the production of good quality fertilizer blends.

It is the sincere of hope the organizers that this workshop will contribute to the quest of ensuring that quality fertilizers are made available to the teeming farmers of Nigeria.

1.0   INTRODUCTION

This write-up on solid fertiliser blending has been prepared by the Fertilizer Producers and Suppliers Association of Nigeria (FEPSAN) under the aegis of Alliance for a Green Revolution in Africa (AGRA) with financial support of The Bill and Melinda Gates Foundation and Partners.
FEPSAN has the following Goals and Objectives:

a)   Improving the production and regular supply of quality fertilizers through   linkages in sourcing of raw materials, finished products and market outlets for members.

b)   Liaise and collaborate with other related associations and stakeholders for policy dialogue and advocacy on agricultural policy and particularly fertilizer policy reforms in Nigeria.

b)   Providing the development of its members through training, education and enlightenment.

c)   Serve as a reference point for data and information on the fertilizer industry in Nigeria.

d)   Promotion of balanced and judicious use of fertilizer in the country.

e)   Collaboration with Government to develop and implement quality control standards and specifications of fertilizer products.

f)   Development and improvement of the fertilizer market chain.

The contents herein, if followed, should lead to improved quality of finished products, and a wider acceptability of blended fertilisers in the Nigerian marketplace.

1.1   WHAT IS FERTILIZER?

Fertilizers are any natural or manufactured material, which contains at least 5% of one or more of the primary nutrients (N, P_2O_5 or K_2O). Industrially manufactured fertilizers are called *mineral fertilizers*. **Mineral fertilizer** is a material in which the declared nutrients are in the form of inorganic salts obtained by extraction and/or by physical and/or chemical industrial processes also termed fertilizer. **Organic Fertilizer** is a fertilizer material of animal or plant origin. It should be noted that sometimes some materials might be applied to soil primarily to improve the physical condition of the soil, in particular to correct soil acidity or alkalinity. Such materials may contain plant nutrient but they are not fertilizers. They are referred to as soil conditioners, amendments or ameliorants. Examples include lime for correcting soil acidity, and gypsum for amending sodic soils.

Fertilizers that contain only one primary nutrient are referred to as straight or simple fertilizers. Examples of some straight fertilizers are urea (46%N), ammonium sulphate or sulphate of ammonia (21%N and 23% S), and calcium ammonium nitrate (27%N). Others include single superphosphate (16-20% P_2O_5), triple or treble superphosphate (46% P_2O_5) and muriate of potash (60% K_2O). The terms P_2O_5 and K_2O are conventionally used to express the fertilizer nutrients 'phosphate' or 'phosphorus' and 'potash' or 'potassium'. They are the oxides of the elements P and K. They are inter-convertible: P_2O_5 x 0.43 = P; P x 2.29 = P_2O_5; K_2O x 0.83 = K; K x 1.20 = K_2O.

Those containing two or three of the primary nutrients are called **multi-nutrient** fertilizers, sometimes also called **binary** (two-nutrient) or **ternary** (three-nutrient) fertilizers. Fertilizers that contain two or more major nutrients. For example: Diammonium phosphate, which contains

nitrogen and P_2O_5, and NPK formulations which contain all three major nutrients. Most multi-nutrient fertilizers can be produced by dry bulk blending (physical mixing) of the separate components—such as urea; DAP and MOP are physically mixed to form NPKs or they can be produced by chemical reaction to produce complex compound fertilizers—like reacting ammonia, phosphoric acid, and MOP to produce different grades of NPKs Or by dry or wet granulation of urea, DAP, and MOP to produce NPKs

1.2   History of Fertilizers

The **history of fertilizer** has largely shaped political, economic, and social circumstances in their traditional uses. Subsequently, there has been a radical reshaping of environmental conditions following the development of chemically synthesized fertilizers.

In the 1730s, Viscount Charles Townshend (1674–1738) first studied the improving effects of the four crop rotation system that he had observed in use in Flanders. For this he gained the nickname of Turnip Townshend.

Justus von Liebig

Chemist Justus von Liebig (1803–1883) contributed greatly to the advancement in the understanding of plant nutrition. His influential works first denounced the vitalist theory of humus, arguing first the importance of ammonia, and later promoting the importance of inorganic minerals to plant nutrition. Primarily Liebig's work succeeded in exposition of questions for agricultural science to address over the next 50 years.

In England, he attempted to implement his theories commercially through a fertilizer created by treating phosphate of lime in bone meal with sulfuric acid. Although it was much less expensive than the guano that was used at the time, it failed because it was not able to be properly absorbed by crops.

Sir John Bennet Lawes

At that time in England, Sir John Bennet Lawes (1814–1900) was experimenting with crops and manures at his farm at Harpenden and was able to produce a practical superphosphate in 1842 from the phosphates in rock and coprolites. Encouraged, he employed Sir Joseph Henry Gilbert, who had studied under Liebig at the University of Giessen, as director of research. To this day, the Rothamsted research station the pair founded still investigates the impact of inorganic and organic fertilizers on crop yields.

Jean Baptiste Boussingault

In France, Jean Baptiste Boussingault (1802–1887) pointed out that the amount of nitrogen in various kinds of fertilizers is important.

Metallurgists Percy Gilchrist (1851–1935) and Sidney Gilchrist Thomas (1850–1885) invented the Gilchrist-Thomas process, which enabled the use of high phosphorus acidic Continental ores for steel making. The dolomite lime lining of the converter turned in time into calcium phosphate, which could be used as fertilizer, known as Thomas-phosphate.

The Birkeland-Eyde Process

The Birkeland–Eyde process was developed by Norwegian industrialist and scientist Kristian Birkeland along with his business partner Sam Eyde in 1903, based on a method used by Henry Cavendish in 1784. This process was used to fix atmospheric nitrogen (N2) into nitric acid (HNO3), one of

several chemical processes generally referred to as nitrogen fixation. The resultant nitric acid was then used for the production of synthetic fertilizer. A factory based on the process was built in Rjukan and Notodden in Norway, combined with the building of large hydroelectric power facilities. The process is inefficient in terms of energy usage, and is today replaced by the Haber process.

The Haber Process

In the early decades of the 20th century, the Nobel prize-winning chemists Carl Bosch of IG Farben and Fritz Haber developed the Haber process which utilized molecular nitrogen ($N2$) and methane ($CH4$) gas in an economically sustainable synthesis of ammonia ($NH3$). The ammonia produced in the Haber process is the main raw material of the Ostwald process.

The Ostwald process

The Ostwald process is a chemical process for production of nitric acid ($HNO3$), which was developed by Wilhelm Ostwald (patented 1902). It is a mainstay of the modern chemical industry and provides the raw material for the most common type of fertilizer production, globally. Historically and practically it is closely associated with the Haber process, which provides the requisite raw material, ammonia ($NH3$).

Erling Johnson

In 1927 Erling Johnson developed an industrial method for producing nitrophosphate, also known as the Odda process after his Odda Smelteverk of Norway. The process involved acidifying phosphate rock (from Nauru and Banaba Islands in the southern Pacific Ocean) with nitric acid to produce phosphoric acid and calcium nitrate which, once neutralized, could be used as a nitrogen fertilizer.

1.3   Fertilizer Use in Nigeria

As in most parts of tropical Africa, the traditional method of maintaining soil fertility and productivity in Nigeria has, hitherto, been the bush-fallow system whereby arable land is allowed to revert to fallow after 3 - 4 years of continuous cultivation. The system evolved out of natural exigencies and the degree of regeneration of soil fertility is generally dependent on the length of the fallow period, which, in turn, is related to the availability of land. In view of growing human population and other socio-economic pressures, attempts were made to shorten the fallow period from about 7 - 10 years to 2 - 3 years by planting leguminous and grass fallows. Although it was clearly demonstrated that soil fertility could be effectively maintained in this way, its acceptance by the peasant farmer was hampered by the tedium of land preparation with native hoes and the economics of the practice; it was not an easy task convincing a farmer to adopt a system that included unproductive fallows.

The next historical development was to replace the fallow system with the use of manures particularly where there were large numbers of animals. This brought into eminence the agricultural value of Farm Yard Manure (FYM), including poultry dropping, dung and house-hold refuse. By the late 1940s the benefits of FYM had been so established that penning of cattle on the farm and mixed farming were being actively encouraged by the Nigerian Government.

However, with agriculture becoming more and more intensive, coupled with the introduction of higher-yielding and more nutrient demanding crop varieties, it became obvious that FYM could not be obtained in sufficient quantities to meet the farmers' demand. Even where available,

transportation problem and labour costs (unavoidably) limited its use on a routine basis. In the circumstance, attention was turned to mineral fertilizers as the alternative.

The first recorded indication of the potential values of inorganic fertilizers in Nigeria was in 1937 when it was shown that response of cereal crops to small applications of FYM was matched by the use of Single Super-phosphate (SSP) containing quantities of phosphate equivalent to that in the organic manure.

The need to apply mineral nutrient elements to depleted soils to resuscitate plant productivity heralded the birth of series of fertilizer experiments on the response of crops to elements such as nitrogen, phosphorus and potassium (NPK). These efforts marked the beginning of fertilizer consumption in the country. Fertilizer consumption figures date back to the late 1930s while actual usage by farmers did not commence until the late 1940s when the West African Oil Seed Mission recommended the supply of phosphate fertilizers to boost groundnut production.

2.0 DEFINITIONS

Throughout this handbook the general terms **blend** and blending are used to denote the product and the process of mixing granular materials. Blended fertilisers may be supplied to farmers in bags or in bulk. The term **bulk-blend** is reserved for situations where the blend is handled (stored, transported) in bulk rather than in bags. Blends do not necessarily consist of mixtures of straight fertilisers or single compounds. A blend of two or three granular complex fertilisers will still be a blended fertiliser.

A number of other specific terms are used and these are defined as follows:

Acidic fertilizer: Fertilizer capable of increasing the acidity of the soil by continued applications.

Adulteration: A fertilizer is deemed adulterated:
  (a) If it contains any deleterious or harmful ingredient in sufficient amount to render it injurious to beneficial plant life when applied in accordance with directions for use on the label, or if the label does not contain adequate warning statement or directions for use that may be necessary to protect plant life.
  (b) If its composition falls below or differs from that which it is purported to possess by its labeling
  (c) It contains unwanted crop seed or weed seed.

Application: General term for all processes of administering fertilizer and soil conditioners to a crop or soil or both. The term embraces broadcasting, spreading/spraying, or dusting, as well as more special placement methods including injection into soil and drilling of seed and fertilizer combined. It may be broadened to cover nutrient film techniques and addition of fertilizers to irrigation water (fertigation).

Basic fertilizer: Fertilizers which increase the pH and the soil on continued use by leaving a basic residue in the soil

Blended fertilizer: A fertilizer obtained by dry mixing that has a declarable content of at least two of the plant nutrients nitrogen, phosphorus and potassium, without any chemical reaction.

Bulk: Qualification given to a fertilizer or soil conditioner not packed in a container.

Brand: Term, design, or trademark used in connection with one or several grades of fertilizer

Coated fertilizer: Granular fertilizer that is covered with a thin layer of a different material in order to improve behavior and/or modify the characteristic of the fertilizer

Complex fertiliser: Compound fertiliser obtained by chemical reaction, by liquid solution or, in the solid state, by granulation and having a declarable content of at least two of the major nutrients.
Note 1: For the solid granules, each particle contains all the nutrients approximately in their declarable content.
Note 2: Some Companies use the term "uniform" to mean a complex fertiliser and to indicate the product is not a blend.

Complete fertilizer: A single fertilizer material containing the entire three major plant nutrients viz, N, P and K

Compound fertiliser: Fertiliser having a declarable content of at least two of the nutrients nitrogen, phosphorus and potassium, obtained chemically or by blending, or both.
Note: With these definitions, mono and di-ammonium phosphates and potassium nitrate are not "straights" but are NP and NK complex fertilisers respectively.

Dose Rate, Dose: The mass or volume of a fertilizer or soil conditioner or nutrient applied to unit area of cultivated land or unit mass of growth medium

d50 (Mean particle size): That size such that half the particles, by mass, are larger than that size and half are smaller.

Fertilizer grade: This refers to the minimum guarantee with regard to the nutrient content of the fertilizer mixture in terms of N, P and K.

Fertilizer formula: This related to the quantitative expression of the analysis of the different ingredients included in the mixed fertilizer in terms of N, P and K.

Fertilizer ratio: This indicates the relative percentage of N, P_2O_5 and K_2O in the manure mixture.

Fertilizer Unit: The unit mass of a fertilizer nutrient (in) the form of the element or an oxide, generally 1 kg

Filler: It is called as the 'make-weight' material added to the fertilizer mixtures. Filler materials are inert materials like sand, saw dust etc, are added to make up the difference between weight of ingredients added to supply the plant nutrients in a tonne and the final weight viz., 1,000 kg.

Fines: Fertilizer particles that are smaller than the size of particles intended to be manufactured for sale.

Formula Weight: Formulas are calculated so that the total weight equals 2204 pounds (or 1002 kgs) when using the metric system.

Guarantee (of composition): Quantitative and/qualitative characteristics with which a material product must comply for contractual or legal requirement. Other related terms are *Declared Content*, *Guaranteed Analysis*

Granular fertiliser: Solid fertiliser formed into particles of a predetermined mean size by granulation.
Note: In some countries, this term is often (wrongly) used to mean complex fertilisers.

Granulation: Technique using processes such as agglomeration, accretion, compaction, to modify the particle size.

Granules: Relatively spherical particles produced by enlarging small particles through successive deposition of a liquid or slurry material, which solidifies on the surface through crystallization and/or drying. The surface of granules is not as smooth as that of prills.

Granulometric spread index (GSI): Measure of the spread of particle sizes and a means of expressing the granulometric spread.

Heavy metals: An element having high atomic weight and specific gravity above 5. Most micronutrients are also heavy metals (such as: Fe, Mo, Mn, Ni, Cu, and Zn).

Increment: Representative quantity of material taken from a sampling unit.

Label: Piece of paper or plastic, or a printed area of a package or container, marked with necessary information to identify the product and make known its essential characteristics.

Liming material: Any material capable of neutralizing soil acidity

Lot: Total quantity of material, assumed to have the same characteristics, to be sampled using a particular sampling plan.

Mean particle size (d_{50}): That size such that half the particles, by mass, are larger than that size and half are smaller.

Misbranding: A fertilizers is so termed:
(1) If its labeling is false or misleading in any particular
(2) It is distributed under the name of another fertilizer product
(3) If it is not labeled as required by regulation
(4) If it purports to be or is represented as a fertilizer, or is represented as containing a plant nutrient or fertilizer unless such plant nutrient or fertilizer conforms to the definition of identity, if any, prescribed by regulation.

N-P-K: Nitrogen-Phosphate-Potash; also, the first three numbers in a fertilizer grade. For example, a 17-17-17 labelled fertilizer product would contain 17% nitrogen, 17% available phosphate and 17% soluble potash. In this section they will be referred to as nitrogen, phosphate, and potash

Neutral fertilizer: Materials which are neither increasing nor decreasing the pH of the soil

Particle size: Dimension which corresponds to the smallest sieve aperture size through which a particle will pass if presented in the most favourable attitude.

Nutrients: The *Fertilizer Act* and *Regulations* has definitions for major plant nutrients (means nitrogen (N), phosphorus (P), or potassium (K)); and lesser plant nutrients (means any plant nutrient other than nitrogen, phosphorus and potassium)

Particle size analysis by sieving: Division of a sample by sieving into size fractions.

Plant Food Ratio: The ratio of the numbers of fertilizer unit in a given mass of fertilizer expressed in the order N-P-K. In other words, it is the ratio of two or more nutrient percentages to another. A 5-10-10 grade has a 1-2-3 ratio; a 10-20-20 a 1-2-2 ratio; 0-10-20 a 0-1-2 ratio.

Prills: A granule obtained by solidification of fertilizer or crystallization under special conditions.

Raw material: Solid, granular material used as a component in a blended fertiliser.
Note: Some of these materials are not the basic source materials which provide the nitrogen, phosphate and potash. In these cases, they are often known as intermediates or pre-mix.

Segregation: Differential movement of particles within a mixture due to differences in their size, shape or density, resulting in their separation.

Sieving: Process of separating a mixture of particles according to their sizes by one or more sieves.

Size guide number (SGN): 100 times the d_{50} measured in millimetres

Soil conditioner: material added to soils to improve the physical and/or chemical properties and/or biological activity

Solubility of a Fertilizer Nutrient: The quantity of a given nutrient that will be extracted by a specific medium under specified conditions, expressed as a percentage of by mass of the fertilizer. The term 'available' as applied to each of the three primary fertilizer constituents, nitrogen, phosphorus and potassium, has somewhat different meanings. For each nutrient, all the content that is soluble in water is available. In addition, however, some of the content that is not soluble in water is available to plants. 'Available plant nutrient' is intended to mean that which is in form capable of being converted into such a form the soil during the growing season.

Specifications: These are requirements with which a fertilizer should conform, as agreed upon between buyer and seller. Fertilizer specifications meet different requirements depending on the use or intent of the specification information.

Spreading width: Distance between the extreme left and right points where the fertiliser arrives on the ground.

Straight fertiliser: Qualification generally given to a nitrogenous, phosphatic or potassic fertiliser having a declarable content of only one of the plant nutrients nitrogen, phosphorus or potassium.
Note: It is possible for a straight fertiliser to be a blend. For example, a mixture of granular ammonium nitrate and granular ammonium sulphate would be a straight nitrogen fertiliser.

Test sieving: Sieving with one or more test sieves.

Toxic elements: Elements which have a toxic or harmful effect on life of plants or micro-organisms. Elements associated with toxicity to plants are fluorine (F), aluminium (Al), lead (Pb), cadmium (Cd), chromium (Cr), selenium (Se), and mercury (Hg).

Toxicity: Adverse reaction of plants due to certain elements in soil or water which are taken up by plants and accumulated to a high concentration, resulting in plant damage or reduced yield.

Threshold value: The concentration of a nutrient/element in the plant, soil or water above or below the optimum level for plant growth. The term is also used for indicating deficiency, toxicity or pollution levels

Unit: One per cent of the formula weight or 20 pounds (or 9.1 kgs). A formula containing 17% of a nutrient would contain 17 units or 374 pounds (or 170 kgs) per tonne. Formulas can be calculated using various computer programs or they can be "hand calculated." This advisory will cover "hand calculating" formulas. Some type of form should be used to record the calculations and to make it easier to check the results.

Working width: Distance between each passage (generally between 12 and 48 m) when spreading fertilisers.

Definitions of other technical terms may be found in Nigerian Industrial Standards for fertilizers (NIS 106 parts 1-11)

3.0   BLENDED FERTILISERS

The blending of solid granular materials to produce a wide range of compound fertilisers has been successfully practised for over 40 years. Fertilizer blends form by far the major proportion of compound fertilisers sold in Nigeria.

Advantages

All the three major plant nutrients are made available in one and the same material. There is saving of time and labour. The residual effects will not be there. The fertilizer mixtures are usually prepared taking into aaccount the acidic or alkaline nature of the ingredients, and other chemical reactions. Hence, some of the residual effects like acidity will not be there. Usually mixed fertilizers are prepared to suit a group of crops and soils. Thus, specifically matching local soil conditions and plant needs, thus avoiding excess nutrients which may enter the environment

Disadvantages

- Specific needs of crops and deficiency of individual nutrient elements cannot be satisfied by using mixed fertilizers as efficiently as in the case of straight fertilizers.
- The use of mixed fertilizer in such cases of specific needs will be a waste as other nutrients are also added to the soil.
- Unit cost of the various nutrients contained in the mixed fertilizer will always be higher when compared to the unity cost of nutrients contained in the straight fertilizers.

3.1   FERTILIZER BLENDERS

Blenders, in common with other fertiliser producers, have a clear responsibility to ensure that their products are of high quality. Raw material producers have a clear responsibility to ensure that the materials they supply to the blenders are also of a consistently high quality and conform to the agreed specifications. That is to say, they supply materials of guaranteed analysis in terms of their nutrient contents and physical properties.

The blender is responsible for his choice of equipment and for specifying the quality of raw materials he is purchasing. In addition, he has a responsibility to check the quality of the raw materials he receives and to monitor his production at all stages to ensure finished products are of the highest quality.

Fertiliser blenders are handling materials which, if mismatched or mishandled, can result in very poor-quality finished fertiliser which will not transport, store or spread satisfactorily. There is a clear economic benefit to suppliers and users alike in improving the quality of blended fertilisers. Poor quality products can have serious consequences, both legal and financial.

This write-up contains practical advice to help manufacturers achieve high quality blends.

3.2   SERVICES AND SOIL ANALYSIS

Whilst the blender's responsibility for the product effectively finishes with its delivery to farm, the responsibility to provide as complete a service as possible does not. Indeed, with modern systems of custom blending, the responsibility starts and finishes on the farm.

Blending can be considered to be a complete system provided for the farmer, starting with soil sampling, analysing its nutrient requirements, and finishing with the accurate spreading of the correct blend of nutrients. It is worth stating some fertilizer companies in Nigeria have realized this and have incorporated soil information as a strategy.

4.0   RAW MATERIALS

There is no gainsaying the fact that the quality of the finished product depends almost entirely on the raw materials. Good blending starts with good raw materials. It is not realistic to expect to make good quality blended fertilisers from poor raw materials. The specification, purchase and checking of raw materials must be the first priority of the blender.

Every raw material should be bought to as tight a specification as possible. Deliveries must be checked regularly, preferably by independent inspectors, to ensure consistent quality. All sampling and testing should be carried out using methods agreed between supplier and purchaser, based either on the Nigerian National Fertilizer Quality (Control) Act or ECOWAS legislation or on accepted Regional or International Standards (CEN, ISO etc.).

Whilst many fertiliser raw materials may be considered to be commodities, rather than speciality chemicals, the opportunistic purchase of spot consignments of doubtful origin and quality is NOT RECOMMENDED. No raw material should be purchased without an agreed contractual specification covering, as a minimum, the registration to REACH, the chemical analysis and the particle size details. Thus, both the chemical and physical properties of the material s are important.

4.1   CHEMICAL PROPERTIES

The nutrient content of each raw material used must be known in order to prepare formulations for the different compounds required. Raw material suppliers should be asked to supply certificates of analysis for each large consignment. Where consignments differ markedly, they should be stored separately and the formulations adjusted to take account of the true analysis.

The water content of each raw material used must be known in order to ensure compatibility between raw materials. In all cases it is advisable to make occasional random checks by arranging for representative samples to be taken by independent inspectors. These samples should be analysed as soon as possible and before the consignment is used.

4.1.1 Compatibility

Some raw materials are not compatible with others and blends containing such mixtures will be of very poor quality. The compatibility data are presented in the table below in three categories (Figure 1).

Fertilizer compatibility table (triangular matrix). Row and column products (in order):
AMMONIUM NITRATE; CALCIUM AMMONIUM NITRATE (AN + DOLOMITE/LIMESTONE); CALCIUM NITRATE (FERTILIZER GRADE); AMMONIUM SULPHATE NITRATE; POTASSIUM NITRATE/SODIUM NITRATE; AMMONIUM SULPHATE; UREA; ROCK PHOSPHATE; ACIDULATED ROCK PHOSPHATE; SINGLE/TRIPLE SUPER PHOSPHATE; MONOAMMONIUM PHOSPHATE; DIAMMONIUM PHOSPHATE; MONO POTASSIUM PHOSPHATE; POTASSIUM CHLORIDE; POTASSIUM SULPHATE/MAGNESIUM SULPHATE (KIESERITE); NPK, NP, NK (AN BASED); NPK, NP, NK (UREA BASED); LIMESTONE/DOLOMITE/CALCIUM SULPHATE; SULPHUR (ELEMENTAL).

Row product	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2 CALCIUM AMMONIUM NITRATE	(green)																	
3 CALCIUM NITRATE	1	8																
4 AMMONIUM SULPHATE NITRATE	2	(green)	10															
5 POTASSIUM NITRATE/SODIUM NITRATE	(green)	(green)	10	2														
6 AMMONIUM SULPHATE	3	2	10	2	13													
7 UREA	4	4	10	4	(green)	(green)												
8 ROCK PHOSPHATE				12														
9 ACIDULATED ROCK PHOSPHATE	5			5			16											
10 SINGLE/TRIPLE SUPER PHOSPHATE	5	9	10	9			17											
11 MONOAMMONIUM PHOSPHATE			10															
12 DIAMMONIUM PHOSPHATE			10						19	19								
13 MONO POTASSIUM PHOSPHATE			10															
14 POTASSIUM CHLORIDE	6	6	10	6			18											
15 POTASSIUM SULPHATE/MAGNESIUM SULPHATE		11																
16 NPK, NP, NK (AN BASED)	6	6	10	6	14	6	4			5	5			6				
17 NPK, NP, NK (UREA BASED)	4	4	10	4	15					16	16					4		
18 LIMESTONE/DOLOMITE/CALCIUM SULPHATE										19	19							
19 SULPHUR (ELEMENTAL)	7	7	10	7	7											7		

Legend:
- Green = Compatible
- Yellow = Limited compatibility (chemically, physically and/or safety based)
- Red = Incompatible (chemically, physically and/or safety based)

Notes for the numbers in the boxes in the compatibility table

Limited Compatibility

1. Due to the hygroscopic behaviour of both products, the type of stabilisation of the ammonium nitrate grade could influence storage properties.

2. Consider the safety implications regarding detonability of the blend (AN/AS mixtures) and legislative implications.

3. Consider the safety implications regarding detonability of the blend (AN/AS mixtures), impact of free acid and organic impurities, if present, and legislative implications.

4. If free acid is present it could cause very slow decomposition of AN, affecting, for example, packaging.

5. Consider the possibility of self-sustaining decomposition and the overall level of oil coating.

6. Due to the hygroscopic behaviour of both products, the type of stabilisation of the ammonium nitrate-based fertilizer could influence the storage properties.

7. Consider the moisture content of the SSP/TSP.

8. Consider the relative humidity during blending.

9. Risk of formation of gypsum.

10. No experience but this can be expected to be compatible. Confirm by test and/or analysis.

11. Consider impurities in AS and the drop in the critical relative humidity of the blend.

12. Consider the likely impact of additional nitrate.

13. Consider the possibility of ammonium phosphate/potassium nitrate reaction with urea and relative humidity during blending to avoid caking.

14. If free acid present, there is a possibility of hydrolysis of urea giving ammonia and carbon dioxide.

15. Formation of very sticky urea phosphate.
16. Potential caking problem due to moisture.
17. If free acid is present, consider the risk of a reaction e.g. neutralisation with ammonia and acid attack with carbonates.

Not Compatible
NC1. Mixture will quickly become wet and absorb moisture resulting in formation of liquid or slurry. There could also be safety implications.
NC2. Sulphur is combustible and can react with nitrates e.g. AN, KNO3 and NaNO3.

From the chart, it is clear that urea and ammonium nitrate should never be used together as the mixture will quickly become wet and absorb moisture. Blends containing urea and single or triple superphosphate may also become sticky and cake. Such blends should never be bagged.

Mixtures of di-ammonium phosphate and superphosphates should be avoided as chemical reactions may take place which can lead to caking or changes in the solubility of the phosphate. For reasons of safety, it is very important to avoid blending ammonium nitrate or raw materials containing ammonium nitrate with any organic materials.

4.2   PHYSICAL PROPERTIES

The most important physical property - as far as blending is concerned - is **the particle size distribution**. The particle size distribution must be known in some detail and the specification must include a full description of this property. At the very least, **the mean particle size (as measured by the d_{50}) must be specified**. Ideally, the specification should include a measure of the granulometric spread index (GSI) and should also include maximum values for the amounts of oversize (for example > 5 mm) and fines (for example < 1 mm).

The shape and the density of particles could have an influence on the behaviour of the fertiliser during spreading.

Other physical characteristics to be specified must include "free flowing" and "dust free" and possibly hardness and impact resistance. However, these properties are much more difficult to assess using standard test methods. More realistically, it is better to specify that suitable anticaking and/or anti-dust treatment is applied to the raw material and that it should not break down during handling.

In all cases it is advisable to make occasional random checks by arranging for representative samples to be taken and assessed by independent inspectors. It is also recommended that samples be taken during the delivery and tested for size distribution at the blending plant. See Section 9.1.2)

4.2.1   Particle Size

The key factor in producing quality blends is the **size compatibility of the raw materials**. Unless all the ingredients are well matched, segregation will take place every time the blend is handled in bulk. This will lead to unevenness of chemical analysis and possibly, uneven spreading of nutrients on the crops.

The particle size distribution can be expressed in a number of ways but all rely on a sieve analysis of the material. **It is essential therefore that blenders should have the facility to carry out a full sieve analysis of their raw materials** (see section 9).

A number of simple field test devices are available but these are limited in their ability to measure particle size distribution adequately. They are however, very useful to carry out spot checks on raw materials being fed to the blender.

The official method of test sieving is fully described in Standards Organisation of Nigeria NIS 106 – 9 Standard for Fertilizers: Part 9 - Methods of Analysis of Fertilizers. A number of numerical parameters may be calculated from the sieve analysis. These include the mean particle size (d_{50}) and granulometric spread index (GSI). In view of the importance of size distribution, full descriptions of these parameters and the use of the various systems are described below.

However, for the best results, it is recommended that a full size distribution curve is plotted for all raw material samples tested.
The mean particle size (d_{50}) is determined using the following equation: (1)

$$d_{50} = z_n + \frac{(50 - c_n)}{(c_{n+1} - c_n)}(z_{n+1} - z_n)$$

Where:
1 z_n is the nominal sieve mesh in mm for which the cumulative undersize is nearest to but below 50% by mass
2 z_{n+1} is the nominal sieve mesh in mm for which the cumulative undersize is nearest to but above 50% by mass
3 c_n is the cumulative percentage undersize for sieve n
4 c_{n+1} is the cumulative percentage undersize for sieve n+1
NOTE: d_{84} and d_{16} are calculated in the same way by substituting 84 and 16 respectively for 50 in equation (1) above.

An excellent measure of the spread of particles sizes can be obtained using the whole of the linear part (between d_{84} and d_{16}) of the distribution curve obtained from the sieve analysis. The values of d_{84} and d_{16} may be found directly from the graph or by calculation. The spread is the difference between the two:

$$\Delta = d_{84} - d_{16}$$

An important value, known as the **Granulometric Spread Index (GSI)**, is derived from the following formula:

$$GSI = \frac{\Delta}{2\ d_{50}}\ 100 \qquad \text{or} \qquad GSI = \frac{d_{84} - d_{16}}{2\ d_{50}}\ 100$$

4.2.2 Bulk Density

The bulk density of the fertiliser may be measured in accordance with the European Standards EN 1236 (Loose density) or EN 1237 (tapped density). The general principle is to weigh the contents of a cylinder of a known volume. For the tapped density, the cylinder is subject to vibrations and compaction occurs. This value is always higher than the loose density.

The density of the fertiliser can have an influence on the behaviour of the particles during spreading on the field. Severe segregation may occur if the densities are very different (see section 5.3).

Generally, the loose bulk density of fertilisers is between 900 and 1100 kg/m3 but extreme values can be between 750 and 1350 kg/m3. In practice these extreme values rarely occur simultaneously.

4.2.3 Shape

The measurement of the shape of the fertiliser particles is not easy. Generally, it is necessary to use image analysis techniques. However, the measurement of the angle of repose of a heap formed by a fertiliser flowing from a funnel can be a useful guide to this parameter. The method is standardised in the European Standards, EN 12047. Angles of repose vary from about 30° for the most spherical products to 40° for the most angular.

4.2.4 Particle Hardness

During handling and spreading, the fertiliser will be submitted to stresses which can break the particles, for example the impact with the vanes during spreading. This process leads to the production of small grains which cause some problems (segregation, caking). For this reason, the particles should be of a sufficient hardness. Unfortunately, the test methods are not standardised because of the variability of the measurement and the evolution of these parameters with time. If the particle hardness is low, the fertiliser may contain too many small particles and thus may no longer meet the quality criteria.

4.2.5 Dust Content

Some fertilisers have the tendency to produce large amounts of dust. This can cause problems in the neighbourhood of the plant and accentuates the risk of caking. There is no standard test method but with some experience the raw materials presenting this problem are easily detected.

4.2.6 Flow Rate

Normally, the fertiliser must flow freely. If there is any caking or some reaction between the components or with moisture, the flowability of the fertiliser can be reduced. This can lead to problems for all the handling operations.

A standard method for the measure of the flow rate has been developed as EN 13299. About 2 kg of fertiliser is placed in a standard funnel which has a closed aperture of 25mm diameter. Then the aperture is opened and the time for 2 kg to flow out of the funnel is measured. The apparatus is calibrated with defined glass spheres.

Table 1: Common blending raw materials

Name	Abbr	Formula	N	P$_2$O$_5$	K$_2$O	SO$_3$	MgO	CaO
Ammonium Nitrate	AN	NH$_4$NO$_3$	33-34,5					
Calcium Ammonium Nitrate	CAN	CaCO$_3$/NH$_4$NO$_3$	26-28					11
Ammonium Sulphate Nitrate	ASN	(NH$_4$)$_2$SO$_4$/NH$_4$NO$_3$	26			35		
Ammonium Sulphate	AS	(NH$_4$)$_2$SO$_4$	21			60		
Urea		CO(NH$_2$)$_2$	46					
Superphosphates: Single Superphosphate Triple Superphosphate	SSP TSP	Ca(H$_2$PO$_4$)$_2$* Ca(H$_2$PO$_4$)$_2$*		18-20 45-48		30 3		
Potassium Chloride	MOP	KCl			60-62			
Potassium Sulphate	SOP	K$_2$SO$_4$			50	45		
Korn-Kali®		KCl/MgSO$_4$			40	12	6	
Potassium Magnesium Sulphate		K$_2$SO$_4$ + MgSO$_4$			30	42	10	
Ammonium Phosphates : Di-ammonium Phosphate Mono-ammonium Phosphate	DAP MAP	(NH$_4$)$_2$HPO$_4$ NH$_4$H$_2$PO$_4$	18 12	46-48 52-53				
Calcium Carbonate		CaCO$_3$						52
Compacted Dolomite		CaCO$_3$ - MgCO$_3$					20	30
Magnesium Carbonate		MgCO3					10	40
Kieserite		MgSO$_4$				50	25-28	

4.3 STORAGE

Raw material storage must be arranged to avoid:
1 segregation within the materials
2 cross contamination
3 deterioration of the physical quality.
Storage must be arranged to ensure adequate identification of the raw materials.

The recommended type of storage is the horizontal or open bin layout. Ideally the bin should be fed from a conveyor belt system with the discharge fitted with an anti-segregation system such as a spinner or flow splitter (Figure 5).

The European Fertiliser Manufacturers' Association (EFMA) has published detailed guidance on the safe storage of fertilisers.

4.3.1 Moisture Pick-up

Some fertiliser raw materials are hygroscopic which means they can pick up moisture from humid air. Stores holding these materials should be air-conditioned or the material should be covered when not being used. Figure 2 shows the critical relative humidity for a number of common blend components and mixtures. The lower the critical relative humidity, the more moisture will be taken from the air. Generally, the phosphates including the ammonium phosphates have a high critical relative humidity and thus almost never present hygroscopic problems. The opposite applies to nitrates such as calcium ammonium nitrate, ammonium nitrate, and especially calcium nitrate.

For blended and complex fertilisers the critical relative humidity in most cases is **below the average** derived from its components. This can be seen when looking at the data for PK and NPK fertilisers. An extreme example for this is demonstrated by the critical relative humidity of a blend consisting of urea and ammonium nitrate. Such a blend would pick up moisture so quickly that it would be impossible to handle it in a dry state, even if spreading occurs immediately after blending.

COMPONENT	CRIT. REL. HUMIDITY
Triple Superphosphate	93,6 %
Mono-ammonium Phosphate	91,6 %
Di-ammonium Phosphate	82,5 %
Ammonium Sulphate	79,9 %
Potassium Chloride	77,0 %
Urea	74,6 %
Sodium Nitrate	72,4 %
Calcium Ammonium Nitrate	61,3 %
Ammonium Nitrate	59,4 %
Calcium Nitrate	46,7 %
BLENDS OR COMPOUNDS	
PK Fertilizers	69,4 %
NPK Fertilizers	64,7 %
Urea - Ammonium Nitrate	18,1 %
Average data for 30 °C from Adams, Merz et al., Runge et al., Silverberg, Löhner.	

Figure 2: Critical relative humidity of fertiliser salts and mixtures. Values are % relative humidity at 30°C.

4.3.2 Contamination

Cross contamination of raw materials should be avoided as this will obviously affect their chemical analysis and hence the final analysis of the blends.

Ammonium nitrate and other materials containing ammonium nitrate must be kept well clear of organic materials.

Good housekeeping is vital to any blending operation. All spillages should be swept up as soon as possible and all equipment kept clean. Overhead conveyors must be kept in good condition to minimise spillage into other storage areas. The use of special chutes to avoid excessive dust is strongly recommended. Further information on the prevention of contamination is given in Reference 12

4.4   SCREENING

Raw materials should be screened before being fed to the blending unit to remove any lumps or fines which may have formed during storage. If screening is performed after weighing and blending, some of the raw material will be lost and this will alter the composition of the final mix. In such cases there can be no control on the final analysis of the blend. In addition, the screening process may seriously un-mix the components. The use of a scalping screen (for example 10mm mesh) to remove any lumps which may have formed in the system, is acceptable.

4.5   SAMPLING AND TESTING

Random spot checks of the raw materials being fed to the blender are recommended. These may be simple checks of the particle size distribution but if there is any doubt, representative samples should be taken and examined fully. For further information about sampling and physical test methods, refer to Chapter 8

4.6   MICRONUTRIENTS AND CONDITIONING AGENTS

4.6.1   Micronutrients

It is relatively simple to add micronutrients to blended fertilisers either as granular or powder materials, but the homogeneity of distribution is particularly important. As a guide, granular materials should not be used if the micronutrient carrier represents less than 5% of the total weight. In these cases it is preferable to add the micronutrient in powder form with a binding agent to ensure good adherence to the granules. Suitable binding agents include heavy viscosity oils, UAN solutions and water. Alternatively, the micronutrients may be added as a solution which is sprayed directly onto the blend in the mixer. Note however, that oil should not be used when ammonium nitrate forms part of the formulation.

Some national regulations do not allow the use of oil: please check this point carefully.

4.6.2   Conditioning Agents

Anti-caking agents are not normally required if the product is to be used immediately. Products which are to be stored or bagged may require the addition of a small amount of anti-caking agent. It is recommended that a dust-suppressant is added to the blend. Conditioning agents may be applied in the same operation as the micronutrients.

5.0   BLENDING EQUIPMENT

All blending plants should include the following equipment:
  1 Weighing or other proportioning device(s)
  2 Dry mixer
  3 Loading or bagging equipment

In addition, some control equipment is desirable but not essential if the other equipment is reliable.

5.1 SELECTION

This advisory does not set out to recommend equipment over any other but there are various types and their characteristics and advantages are different. The capacity of the equipment should be chosen to match output requirements in terms of tonnes per hour and tonnage per week.

5.1.1 Weighing

In batch operations, the whole equipment may be mounted on a load cell or belt weighers may be used. For continuous blending, individual belt weighers may be fitted to the belts feeding the raw materials to the mixer. The size and type of such equipment should be chosen to match the plant size and outputs required.

5.1.1.1 Unit Batch Weighing

These are the most popular systems. The outputs range from 20 to 100 tonnes per hour. Smaller systems have a floor mounted hopper with load-cell digital read out, fed from a front-end loader. The raw materials are weighed in the proportions determined by the formulation. Batches are then conveyed to the mixing unit.

Larger units are normally fed from overhead holding hoppers.

5.1.1.2 Continuous Weighing

These systems provide a continuous feed to the mixer by belt conveyors and may be continuous belt weighers or constant rate feeders. In the former the raw materials are fed onto fixed speed extractor weigh belts fitted with load-cells. Variations in weight are transmitted to the control unit which adjusts the hopper gate opening. Constant rate feeders have a fixed hopper gate opening and the belt speed is continuously adjusted to the predetermined rate of output. A load cell continuously monitors the amount of material on the extractor conveyor and sends signals to the motor speed control unit. In both systems, information from the individual weight or speed controllers is fed to a central control unit which can be pre-set for the required output.

5.1.2 Volumetric Feeding

For some blending operations it is sufficient to use volumetric measuring of the raw materials to obtain the correct proportions in the blend. A separate hopper, usually fed by front end loader, must be provided for each raw material. All the components are handled simultaneously and the units are controlled to give the required blend ratio.

This system however, relies on consistent raw material densities and many uncontrollable variables may cause changes in the bulk density. One of these factors will be the particle sizes of the granules and these may vary throughout a storage heap.

5.1.3 Mixers

The blending equipment is a major determining factor in the production of good quality blends. Different designs of mixers are available such as rotating drums, cone ended tilting mixers, stationary mixers with internal paddles, vertical mixers and volumetric mixers with variable speed screws. In addition, blending may be carried out without the use of a specific mixer. In this system all raw materials are fed onto a collector belt conveyor and, as each material is constantly fed at the correct weight, all materials are constantly layered onto the belt in the correct formulation ratio. Thus, a cross section of that belt will at any time have the correct nutrient content. Subsequent mixing at belt changeovers as the blend moves through the remainder of the plant ensures a correct mix at all times.

The choice of design will depend on individual circumstances and is outside the scope of this advisory. However, one aspect of mixing which is of importance is the mixing time. Mixing times are normally around two minutes and times above 5 minutes are not recommended because of the risk of particle breakdown and deterioration of the mixing quality.

After installation, the mixer must be tested to determine that satisfactory mixing is achieved. It is recommended that a coefficient of variation of less than 10% is achieved. Descriptions of mixing tests can be found in references.

5.1.4 Loading Equipment

At all stages after the mixing, great care must be taken to avoid segregation of the blend components. This means that coning must be avoided at all stages.

The final section of the blending plant may include receiving hoppers for bulk loading or bagging but in the simplest case the blended material may be loaded directly onto trucks from a conveyor system. Further information on equipment may be obtained from manufacturers or by reference to the literature.

5.2 TESTING/CALIBRATION

As a minimum control, records must be kept of all formulations, batch records, weight or volume settings and raw material analyses and sources. In addition, the following are to be recommended:

>1 Regular checks of weighing or volumetric measuring equipment (minimum frequency, once
>
>per month)
>
>2 Frequent check weighing for bagged material
>
>3 Random checks of the chemical analysis of finished products (**minimum frequency, once a week**)

Further information is given in Chapters 7 and 8

5.3 OPERATIONS

Full written operating instructions must be available for all personnel. Operating procedures should be well documented and reviewed at regular intervals. Accreditation to ISO 9000 is not essential but is recommended as it offers an independent assessment of all procedures.

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6.0 SEGREGATION

Segregation is the separation of particles due to differences in physical characteristics. For segregation to take place there must be movement between the particles.

Various characteristics may cause segregation but the most common are **particle size, particle density and particle shape**. The size is certainly by far the most important factor to explain segregation during flow. During spreading, the three properties play a role, the shape being the least important and the size again having a dominating effect.

From the above it is seen that segregation may occur during manufacture, bulk transport (and handling) or during application to the soil or crops. The effects as seen by the crops may be the same in all cases unless remixing takes place during later handling stages.

The following extract from Stairmand [13] deals with the problems of storage in hoppers and this is relevant to bulk handling, bagging operations and spreading.
"The two main factors are avoidance of segregation in filling and emptying and ensuring the hopper will be "self-clearing." In examining the question of segregation in filling… if the material is charged into the hopper from a single point, the coarser particles will migrate to the outer edges and a central core of material containing an excess of fines will form. If now filling is discontinued and the hopper is allowed to discharge it will do so in zones… If the zones contain particles of different sizes due to segregation in filling, no device fitted at the cone discharge to remix can possibly be effective. If however, the hopper is filled without segregation, little segregation will occur when emptying."

By applying the above to blending, it can be seen that the avoidance of segregation and the subsequent handling of the product, is the most important part of any blending process. This may be achieved in three ways:

1 The careful matching of the blend components

2 The design of hoppers
3 The loading methods of the hoppers and vehicles, etc.

The origin of the segregation is always a difference of physical properties leading to a physical separation of the particles which may or may not result in a chemical segregation. Size segregation may also occur within raw materials or complex fertilisers but this will have no (or very little) effect on the chemical content. However, in bulk blends, physical segregation often leads to chemical differences.

6.1   FLOW SEGREGATION

Care must be taken when storing any material to avoid size segregation in the storage heaps. Whenever granular material falls freely to form a cone or part cone, the larger particles will tend to run down the outside with the smaller particles remaining near the centre of the cone. Should this happen, there may be quite large variations in size characteristics between various parts of a heap and this could have serious effects on all fertilisers (Figure 3). Batches taken from a segregated heap can thus differ in particle sizes, and this will affect the spreading width of a centrifugal spreader with straight, blended and complex fertilisers.
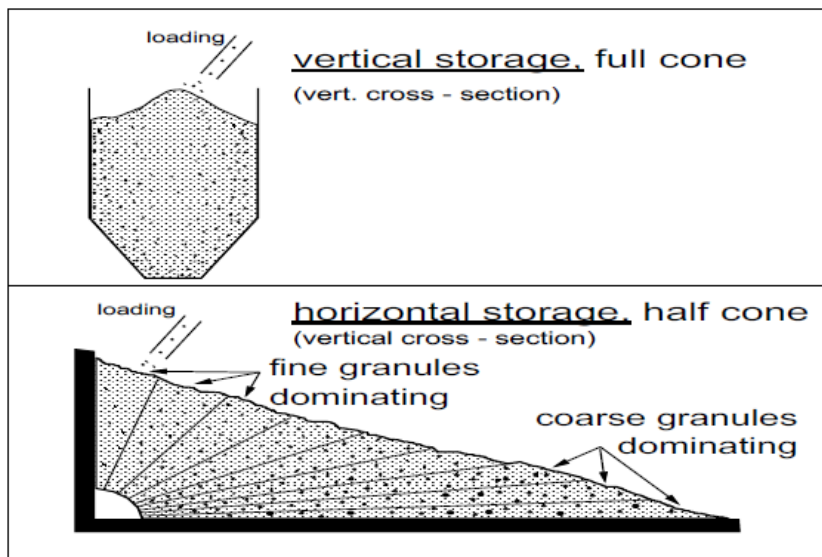
Figure 3. Illustration of flow segregation when coning occurs during loading [15]

There may be some remixing at later handling stages. Such remixing may be caused simply by tipping a bag of fertiliser out into a hopper or even more simply by turning a loosely filled bag over. Remixing may also occur during loading and unloading of bulk fertiliser (Figure 4). However, systematic remixing can rarely be counted on.
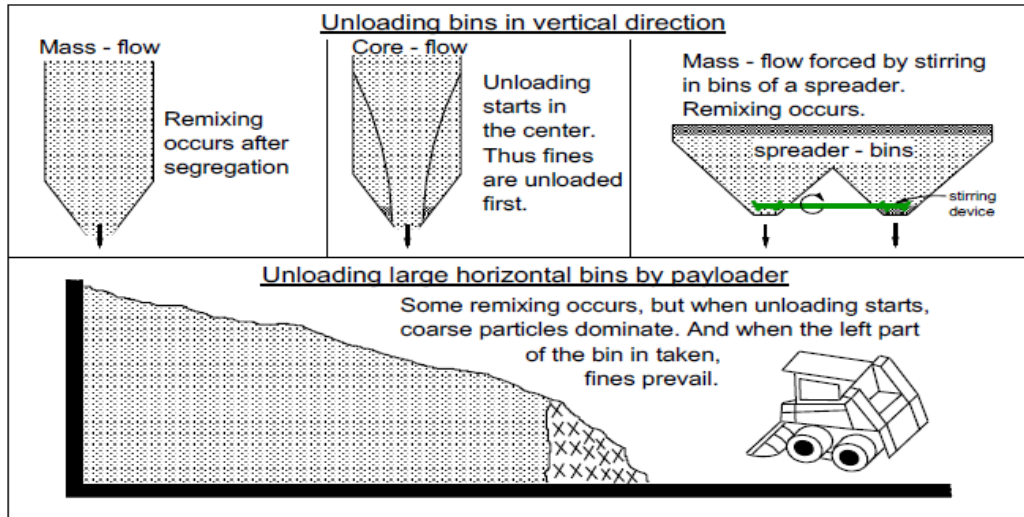
Figure 4. Remixing of segregated fertiliser when unloading bins

It is essential that all handling equipment is constructed to minimise segregation. The use of specially designed chutes is recommended to avoid segregation and excessive amounts of free dust. Examples of techniques which may be used to avoid segregation include (Figure 5): "Egg crate" baffles in square or rectangular hoppers, Concentric cone distributors for cylindrical hoppers, Flexible spouts for direct loading equipment.
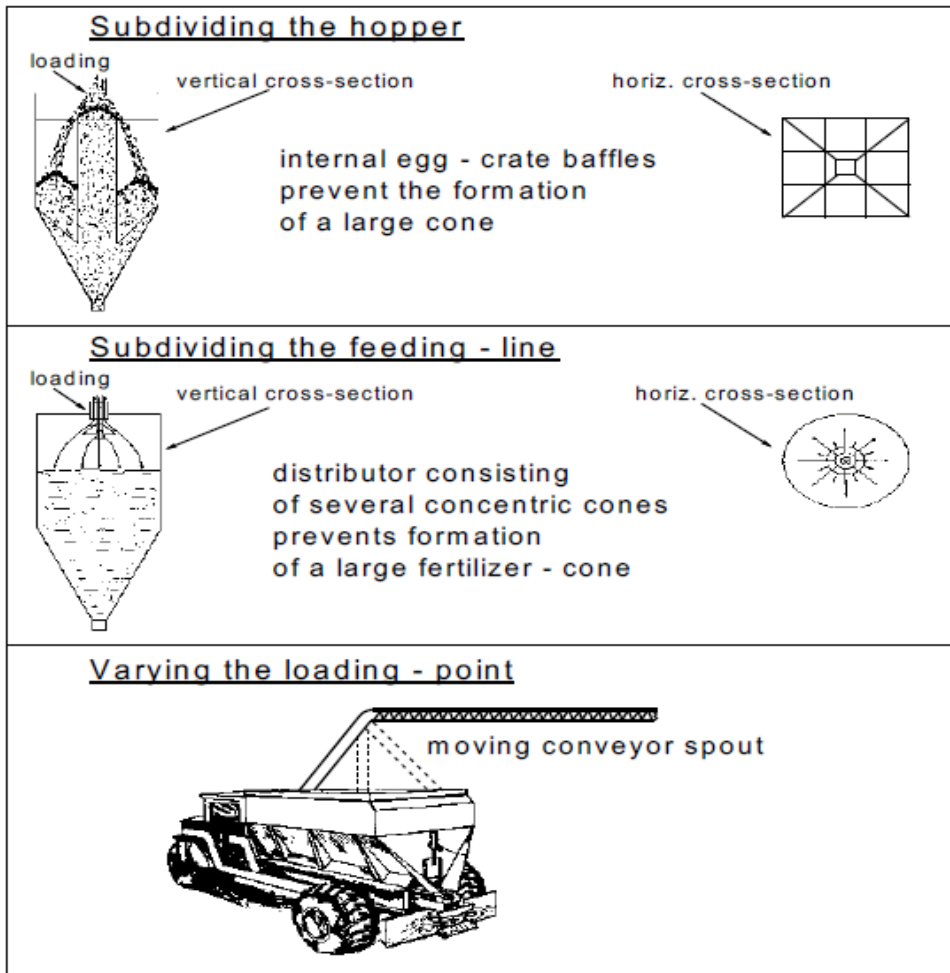

Figure 5 – Prevention of segregation in hoppers

In the case of raw materials, the segregation is mainly a size segregation which has little effect on the chemical content. For blends, the risk is to have both size and chemical segregation.

Tests of filling and emptying containers have shown that granulometric segregation is well linked with the granulometric spread index (Figure 6). It is recommended that the granulometric spread index of the blend is limited to below 20. This means that the raw materials must have an even lower GSI.

The figures below distinguish three ranges of segregation: **Low** segregation means that for the given difference of property the final segregation has little impact – **Medium** is the situation where the final segregation begins to be significant but if there is another unfavourable condition, for example low overlapping during spreading, the final result may be bad – **High** is the worst situation where there are negative economic and/or environmental consequences.
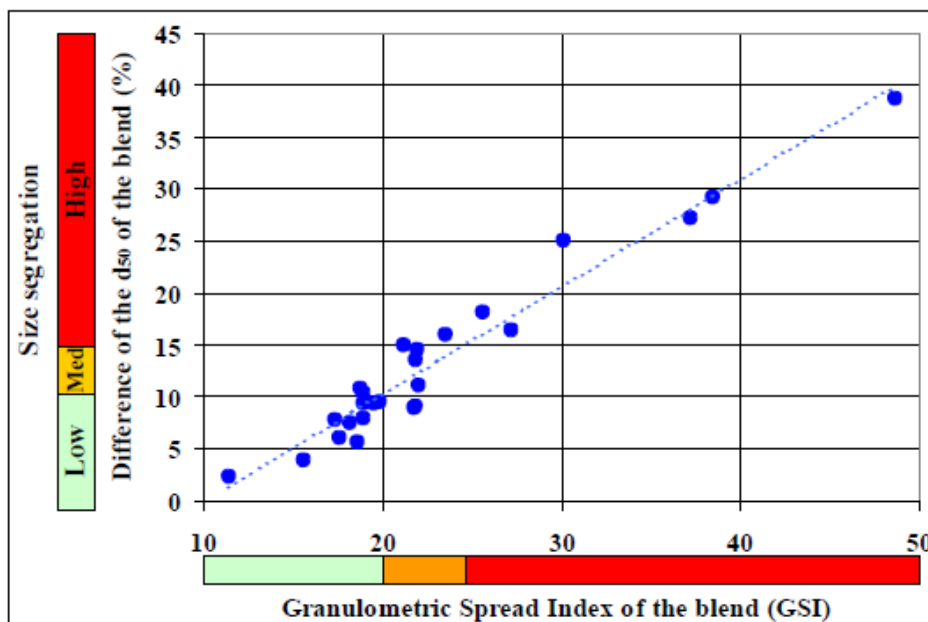

Figure 6: Relation between size segregation and GSI of bulk blends when emptying a container (segregation is the difference of d_{50} between the first and the last third of emptying a container)

Chemical segregation is related to the absolute sum of the difference of d_{16} and d_{84} of each component
(Figure 7). This means that if the fine particles come from one raw material and the coarse particles from another, the size segregation induces a chemical segregation.
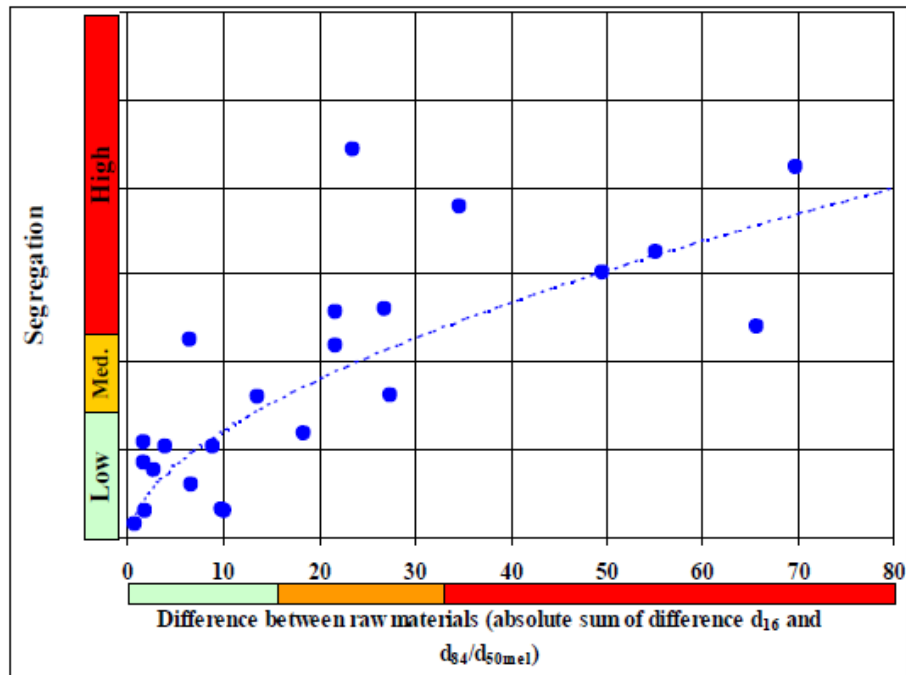
Figure 7: Chemical segregation in relation with the absolute sum of the differences of d$_{16}$ and d$_{84}$ of the components.

6.2 TRANSPORT SEGREGATION

It is often said that blends are subjected to serious segregation during vehicle transport but this is not true. The level of vibration in transport vehicles is not high enough to induce a movement of the fertiliser. In fact, the segregation occurs when filling (and emptying) the container as described above.

During transport, only percolation of very small grains between the larger ones can occur. With common fertilisers, this phenomenon appears if there are particles smaller than 0,5 mm. Above this size, the process is too slow to have a real impact on the final product.

6.3 SPREADING SEGREGATION

Blenders should have some knowledge of the kinds of spreading equipment available and the advantages and disadvantages of these when using blended fertilisers. Blenders should be prepared and able to advise farmers on the type of equipment to use and the setting up, calibration and maintenance necessary. This means that they should be prepared to give as much information as possible about the physical quality of their products. Such information may include the composition, bulk density and flow characteristics as well as the particle size distribution. This is another reason for keeping adequate records of raw materials and product batches.

Centrifugal, pneumatic, and auger spreaders are available. The segregation induced by physical differences of the fertiliser particles may be due to trickling, as is the case with auger spreaders, or may be caused by the aerodynamic resistance of the particles when thrown through the air, as with centrifugal and pneumatic spreaders.

However, any segregation during spreading may be completely compensated for by the overlapping of adjacent spreading swaths. This leads to the question, how much overlapping? As a general guide, pneumatic spreaders will not induce segregation because of the large amount of overlapping (from the spouts). The effects of segregation from centrifugal spreaders will be reduced by overlapping.

Auger spreaders will segregate heavily. Since these spreaders, when correctly adjusted have a rectangular lateral mass distribution, no overlapping occurs and thus also no reduction of segregation takes place. For this reason, auger spreaders are not recommended for blended fertilisers. Further information may be found in European Fertilizer Blenders Association Handbook.

Segregation occurs during spreading due to physical differences between the components of the blended fertiliser. The larger, heavier and more spherical the particles are, the further they are spread. The size and density are the major factors (Figure 8, Figure 9 and Figure 10).

The charts show the segregation as a function of the difference of a given physical property (size, density or shape). The considered blends have two components in a proportion of 50% and these are physically similar except for the analysed property.
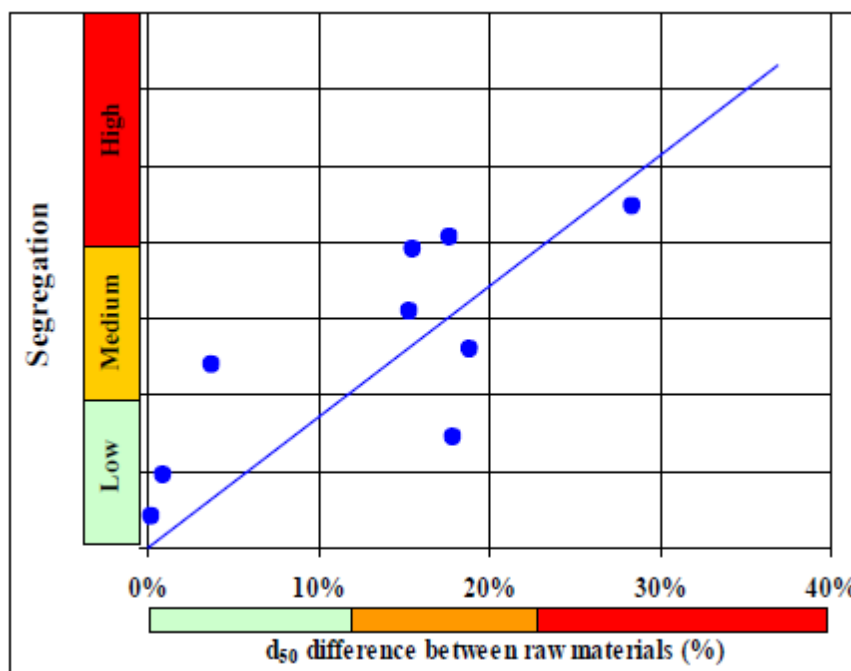

Figure 8: Evolution of the segregation with the difference of d_{50} between the two components
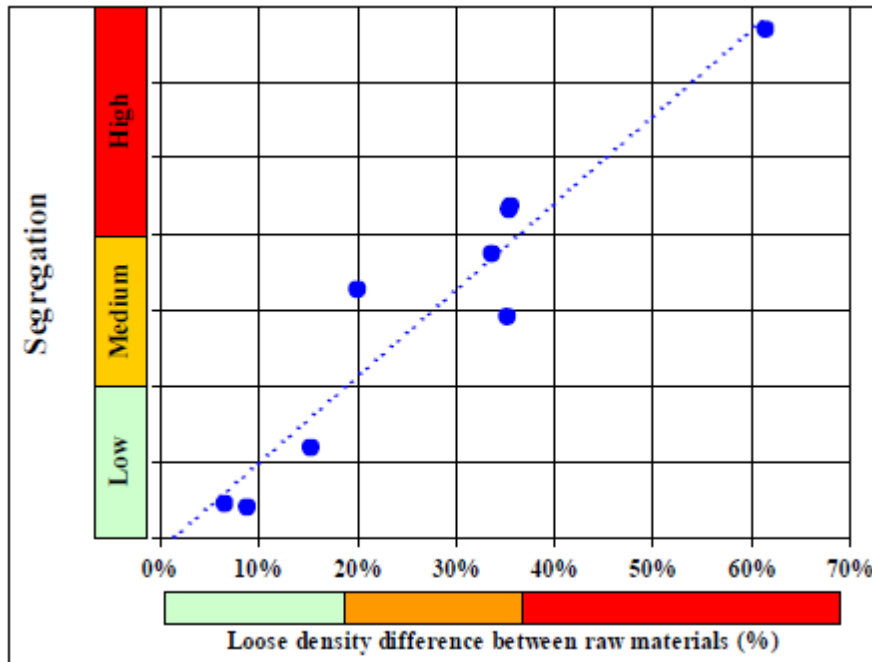
Figure 9: Evolution of the segregation with the difference of density between the two components.
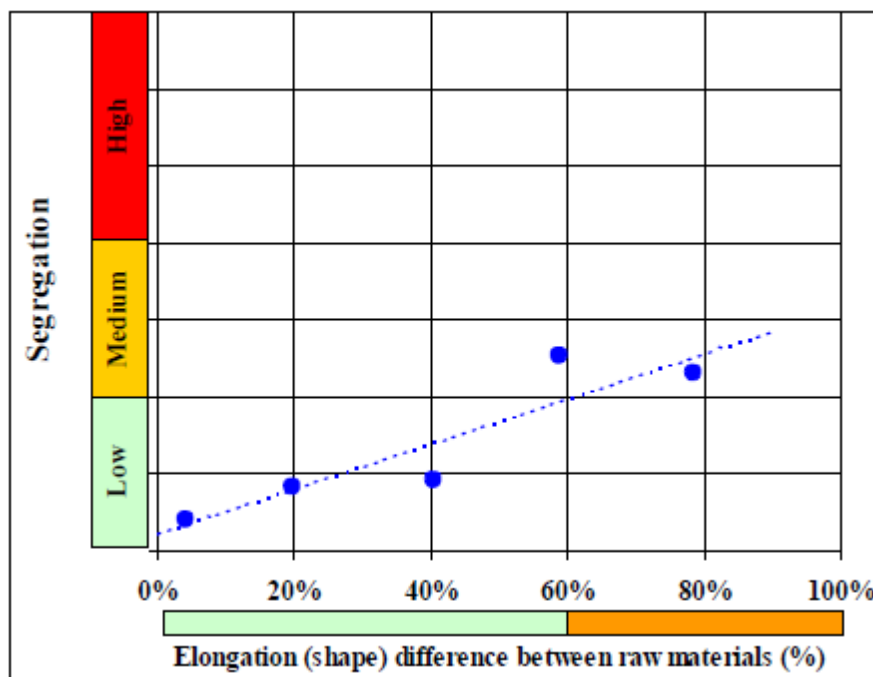

Figure 10: Evolution of the segregation with the difference of shape between the two components

In practice, the components present differences for more than one physical property and each difference can accentuate or reduce the final segregation. For example, size difference between components can compensate for a density difference and vice versa. The larger, heavier and more spherical the particles are, the further they are spread. **For example, urea which has a low density in comparison with other fertilisers should ideally have large sized particles with a d_{50} near the maximum tolerance in order to limit spreading segregation**.

The final impact of segregation during spreading can be significantly reduced by appropriate overlapping between the passes. Indeed, the segregation is generally marked in such a way that one component tends to accumulate behind the spreader and another tends to be spread further. If the overlapping between the passes is sufficient, at each place in the field the final quantity of fertiliser comes from two passes (Figure 11, top and centre). With a good spreader correctly adjusted, it is even possible for working widths up to 24 or 28 m. However, for badly adjusted spreaders the segregation remains. Practically, a correct overlapping means that the spreading width must be about double the working width. So, with a working width of 24 m, it means that the spreading width must approach 48 m. Figure 11, below, shows an example of insufficient overlapping, resulting from a working width which is much greater than half the spreading width.
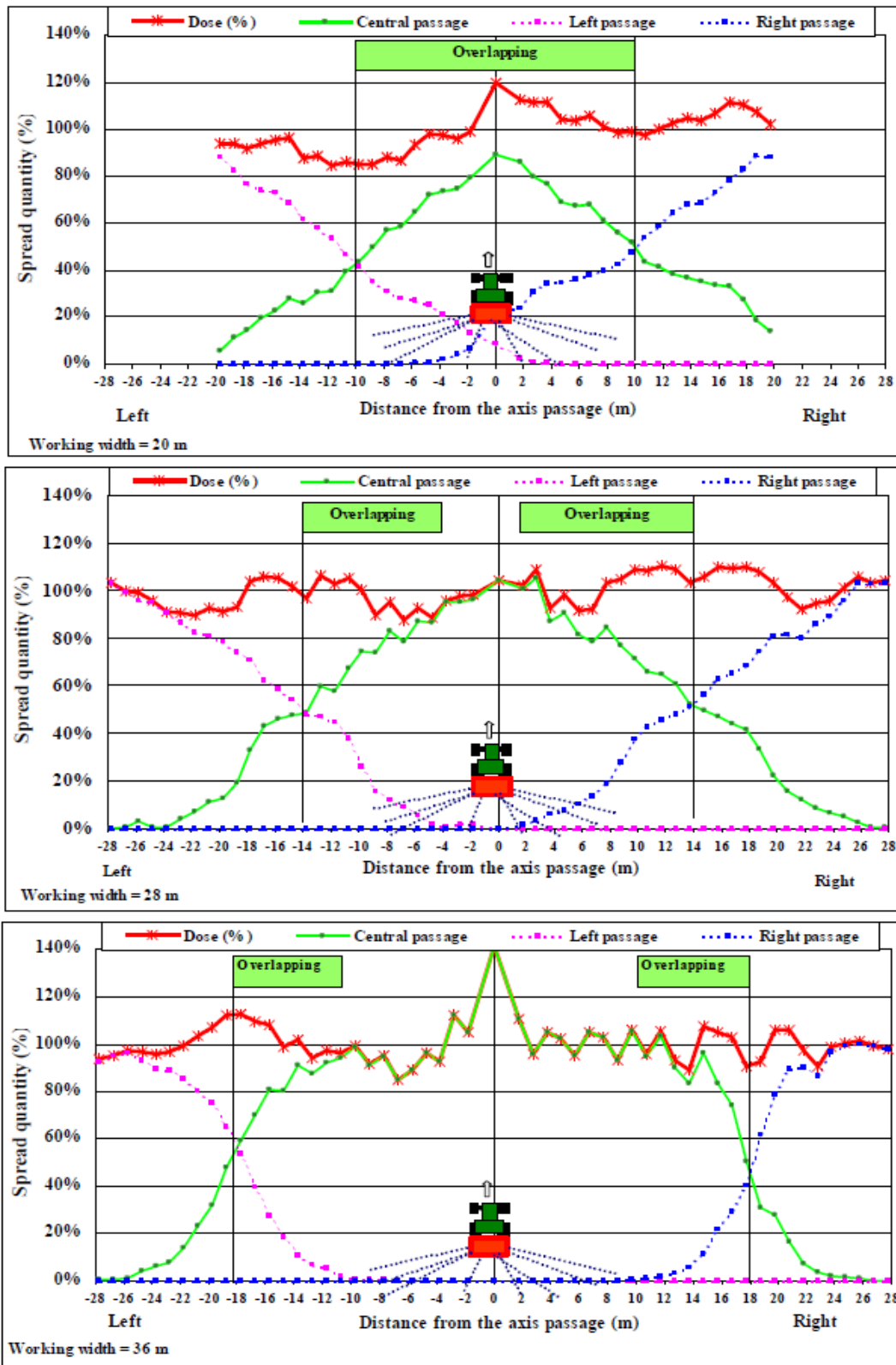
Figure 11: Illustration of the overlapping for the same bulk blend but for working widths of 20, 28 and 36 m.

Another important point to mention is that with higher working widths, it becomes difficult to find the correct adjustment. This is not only the case with blends but also with straight or complex fertilisers.

Good advice for farmers is to **limit the working width in order to obtain an important overlapping**. In practice this means choosing a working width lower than 24 or 28 m with a high performance
spreader.

6.4 QUALITY RECOMMENDATIONS TO REDUCE SEGREGATION

To reduce segregation problems, it is recommended to blend raw materials **having similar physical properties**, the most important being the size of the particles. The SON has defined quality recommendations for the particle sizes (NIS 106:9).

7.0 SAFETY CLASSIFICATION – LABELLING - DISTRIBUTION

Blenders must be aware of the hazards associated with raw materials and fertilisers, especially those containing ammonium nitrate. Recognition of the hazards is made simpler by classification systems such as those prepared by the United Nations (UN), International Maritime Organisation (IMO) and the European Commission (EC). All products must be labelled according to NIS 106: 11 and other regulations and in some circumstances only packaged fertilisers may be supplied to the end user.

Full account should be taken of all industry guidance and Codes of Practice such as those prepared by Standards Organisation of Nigeria (NCP 10) and as contained the Fertilizer Quality Control Act 2019.

7.1 Labelling and marketing of fertilisers

Any fertilisers placed on the Nigerian or Sub-Saharan Africa market must be correctly labelled in accordance with either Nigerian (NIS 106:11) or ECOWAS or African Organization for Standardization (ARSO) regulations, dependant on the market in which it is to be sold. These regulations normally cover matters such as product identifier (ingredient disclosure), the name, brand or trademark under which the fertilizer is sold nutrient content, safety and protection of the environment.

7.2 Labelling and classification of hazardous substances and mixtures: hazard labelling

The information required are name or number used for a hazardous product on a label or in the Safety Data Sheets. This should include the chemical identity of the substance (name as determined by IUPAC (International Union of Pure and Applied Chemistry), ISO (International Organization for standardization), or technical name) and the chemical identities of all ingredients (in case of mixtures) that contribute to acute toxicity, skin corrosion or serious eye damage, germ cell, carcinogenicity, reproductive toxicity, skin or respiratory sensitization, or Target Organ Systemic Toxicity (TOST).

Symbols (Hazard Pictograms): Conveying health, physical and environmental hazard information, assigned to a GHS hazard class and category (if applicable).

Signal Words: "Danger" or "Warning" to emphasize hazards and indicate the relative level of severity of the hazard, assigned to a GHS hazard class and category (if applicable).
    "Danger" for the more severe hazards, and

"Warning" for the less severe hazards.

Hazard Statements: Applicable Standard phrases assigned to a hazard class and category that describe the nature of the hazard.

7.3 Regulation related to hazardous substances and mixtures (REACH regulation) : Safety data sheet (SDS)

REACH Regulation 1907/2006/EC on Registration, Evaluation, Authorisation & Restrictions of Chemicals) defines Safety Data Sheet as the main information vector on product hazards and good practices.

A Safety Data Sheet (SDS) is mandatory and is to be pro-actively provided to the client if the final product is classified as hazardous in accordance with CLP Regulation.

A SDS is to be provided to the recipient at his request when the fertiliser does not meet the criteria for classification as hazardous in accordance with CLP, but contains:

• 1 % or more of a substance classified as hazardous

• 0.1% or more of a substance classified as persistent, bio accumulative and toxic or very persistent and very bio accumulative which is on the list of substances submitted to authorisation (REACH)

• a substance for which there are Community workplace exposure limits.

Any SDS shall be provided free of charge.

For fertilisers classified as hazardous, the SDS shall to be provided on paper or electronically no later than the date on which the fertiliser is first supplied. There is no need to provide it at each delivery.

Updates of SDS shall be provided to all former recipients to whom fertiliser has been supplied within the preceding 12 months.

SDS shall be provided in the language of the country where the product is sold.

SDS shall follow the product from its manufacture to it's end use:

Distribution à forwarding of supplier's SDS to the client.

Packaging à Transmission of a SDS in the name the company responsible for placing the fertiliser on the market.

Blending à Transmssion of a SDS specific to the blended fertiliser in the name the company responsible for placing the fertiliser on the market.

The safety data sheet shall be dated and shall contain the following headings:

1. identification of the substance/mixture and of the company/undertaking;

2. hazards identification;

3. composition/information on ingredients;

4. first-aid measures;

5. fire-fighting measures;

6. accidental release measures;

7. handling and storage;

8. exposure controls/personal protection;

9. physical and chemical properties;

10. stability and reactivity;
11. toxicological information;
12. ecological information;
13. disposal considerations;
14. transport information;
15. regulatory information;
16. other information.

A set of Standardised Safety Data sheets for the most common fertilisers are available on request.

Key steps according to hazardous substances regulation:
- Check if presence of hazardous substances in raw materials: superphosphates, ammonium
- nitrate…
- Classify the new fertiliser in accordance to hazardous substances regulation (CLP)
- Label the new fertiliser in accordance with hazardous substances regulation (CLP) when
- needed
- Create the Safety Data Sheet in accordance with REACH if needed

8.0   QUALITY CONTROL

Blenders should draw up a routine quality control schedule to include the sampling and analysis of raw materials and products as well as checks on raw material weighers and/or feeders and check weighing of finished bagged products.

8.1   RAW MATERIALS

The amount of quality control of raw materials depends on the reliability of the suppliers. If supplies are received from single sources, experience will soon establish the degree of control needed. If raw materials are purchased from a variety of sources, extra control is essential.

Random samples from each consignment should be taken as described in Section 9, for reference purposes. These samples can be sent for analysis whenever there is reason for doubt but they should be carefully labelled with date and origin and kept for at least three months.

As mentioned in section 5.2, the **particle size distribution of the raw materials is the most important property to be controlled**. Representative samples of raw material feeds should be taken and tested as detailed in Chapter 9 at regular intervals with a minimum frequency of once per shift. A full sieve analysis should be carried out on each raw material.

8.2   FINISHED PRODUCTS

All blenders have an obligation to meet the requirements of their National Fertiliser Regulations. National Regulations will cover products which are not declared as regional fertilisers. It should be noted that in cases where the farmer does not purchase a fertiliser with a specified nutrient ratio, for example, if he purchases his own raw materials and contracts the blender to mix them for him, all official controls for the blended fertiliser may not apply.

The regulations set out the tolerances on the declared **chemical analysis** for all fertilisers. The Investigational Allowances (Tolerances) allowed by the SON NIS 106-9 has analytical tolerances

referenced. Fertilisers not meeting these tolerances may result in prosecution and penalty, as laid out in the National Fertilizer Quality Control Act 2019. It is therefore recommended that some degree of quality control is exercised by blenders (auto-control).

The amount of quality control required will depend very much on the scale of the blending operation. For simple small-scale batch blending operations, it may be sufficient to rely on the principle that "what goes in must come out". However, even these operations will need some regular control of the weighing equipment.

For large scale continuous operations, consideration should be given to full automated on-line sampling and analysis.

In between these two extremes, it is recommended that one representative random sample is taken from one of the grades made each day. If laboratory facilities are available on site, these samples should be analysed daily. If outside contract laboratory services are used, the frequency of analysis should be **at least one sample per week**, selected at random from the week's collection.

Records should be kept of all samples taken and analyses carried out.

9.0   SAMPLING AND ANALYSIS

9.1   SAMPLING

Representative sampling of any material requires special techniques and equipment. Full details are outside the scope of this write-up but it is recommended that blenders follow recognised sampling methods such as those set out in NIS 106:10.

It is essential that all samples are correctly taken to ensure their representativity. There is no point in taking and analysing unrepresentative samples. The quality of the measurements made on the samples depends on their representativity. This is particularly important for blended fertilisers where the risk of heterogeneity is higher.

As stipulated by regulators elsewhere, **blended samples must always be taken from material in motion**, either in free fall or on conveyor systems. It is essential to sample **through the whole stream** rather than from the same part of the stream. Suitable automated equipment is available for most circumstances and is to be recommended whenever possible.

For the blend producer it is important to know the sampling and measurement methods and the necessary equipment. Generally, all of this is described in standards which are regularly updated. Blenders are recommended to study the latest versions of sampling and measurement standards.

When a sample of any granular matter must be taken, some questions should be asked:
    1 What quantity must I take?
    2 How many increments to obtain this quantity?
    3 How to take the samples?

Finally, the sample must be reduced in order to obtain a final sample for analysis (usually about 250 g for sieving test and 500 g for a chemical analysis). Thus, after the sampling there is also a reduction step. Full details of reduction methods are given in NIS 106:10.

9.1.1 Sampling Quantity

The minimum quantity of sample recommended is given in EN 1482 Part 1. The recommendations are summarised as follows:

Table 1 - Number of Containers or Packages to be selected from a Lot

Lot Size, (N)	No. of containers to be selected, (n)
<28	2
28 – 64	3
65 – 100	4
101 – 300	6
301 – 500	7
501 – 800	8
801 – 1300	9
1300 and above	10

Number of bags Minimal number of increments
If the weight of a bag is less than 5 kg, a complete bag is considered as a sub-sample. The number of selected bags can be higher if the final quantity of the sample is not sufficient.
From Storage Piles – Ten vertical cores shall be taken from sampling points as shown in Figure 9, with any of the triers specified in below
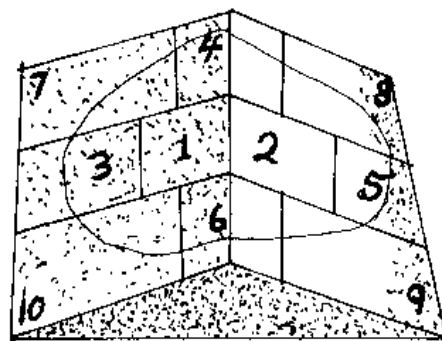

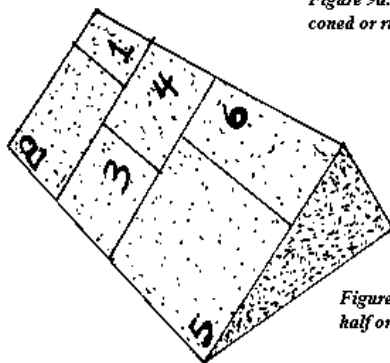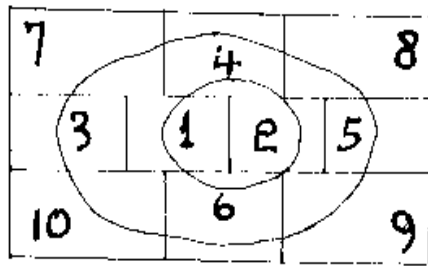Figure 9a: Sampling points for coned or ridged pile.

Figure 9b: Sampling points for half or one sided pile.

From Truck or Wagon Load - Ten vertical cores shall be taken from sampling points as shown in Figure 10, with any of the triers specified below

From Conveyor Belt – Estimate the time lapse for the entire transfer operation and calculate the approximate time interval needed for a ten equal-time-spaced passes. Using the sampling cup specified in 4.2.1(ii) with the slot perpendicular to the falling stream, make ten passes through stream at a uniform rate and at the ten-time interval calculated.
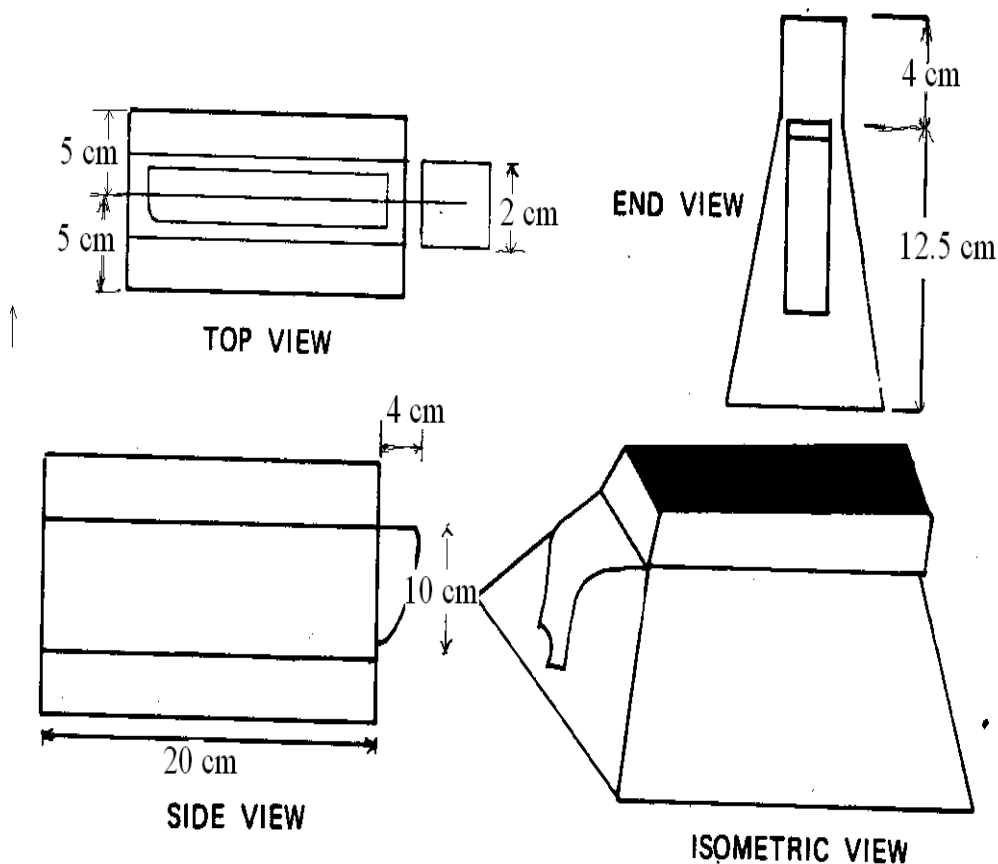
Further information is given in NIS 106:10

9.1.2 Sampling Equipment

Appropriate sampling equipment is essential. There are various automated systems for use with conveyor belts. These are certainly recommended if there are large amounts of fertiliser handled. For smaller deliveries, manual sampling is more suitable. A suitable type of sampling cup is described in NIS 106:10 above and is essential for sampling from falling streams of materials such as from aa conveyor belt.

9.1.3 Sample Divider

Rotary sample dividers are recommended, particularly when sieve analysis is to be carried out or when blends are being tested. Riffle dividers may be used for raw materials but are less suitable for blended products. Descriptions of these dividers (Figure 16) can be found in NIS 106:10. It is important to remember that for the measurement of the physical properties, the particles must not be crushed, but for chemical analysis, it is recommended to crush the particles before the final reduction of the sample.
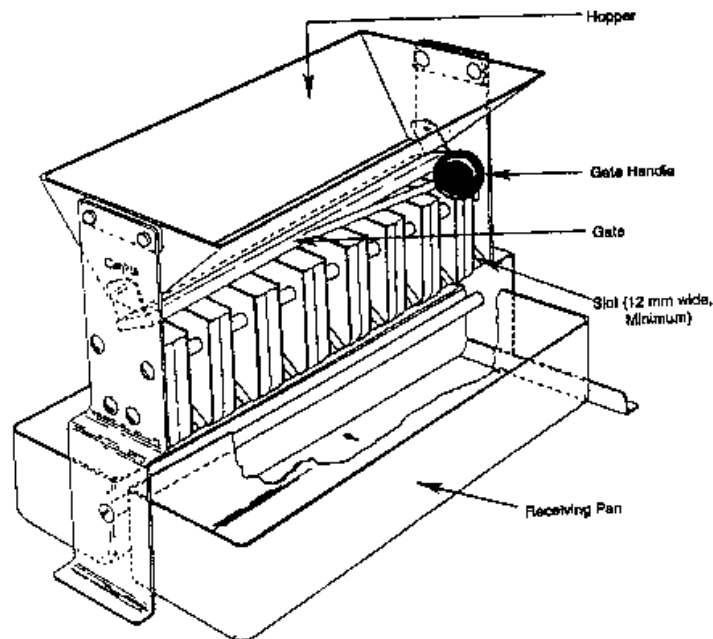

Figure 16: Illustration of rotary or riffle divider

9.2   CHEMICAL ANALYSIS

Standard reference test methods for most of the common chemical analyses used for fertiliser materials may be found in NIS 106:9. It is not essential that these methods are used for routine process control and simpler, often automated, methods are available. However, all such methods must be evaluated against one of the recognised standards.

9.3   PHYSICAL TESTS

Recognised standard test methods exist for several physical properties. The interest of blenders should focus on test sieving and bulk density (see section 4.2). Some laboratories have an accreditation for these special measurements. No Standard methods are available for such properties as caking and free dust.

Sampling is also a fundamental step for physical testing because of the segregation that occurs naturally. This is particularly the case for sieve analysis because of the size segregation when there is a flow of fertiliser (which is always the case for bulk products).

Another point is that for physical testing, the quantity needed for the final sample may be more than 5 kg. This means that the number or the mass of sub-samples must be sufficient to achieve this.

9.3.1 Test Method for Sieve Analysis

The principle is based on dry sieving of a sample of fertiliser material with one or more test sieves, using a mechanical sieving machineas described in *NIS 106:9*

9.3.1 Test Method for Loose Bulk Density

This involves weighing a known volume of the fertiliser as outlined in the European Standard, EN1236.

9.3.3 Test Method for Angle of Repose*:*

Measurement of the diameter of a heap of a given height and calculation of the angle of the heap.

10.0 BLEND FORMULATION

The calculation of blend formulations is not a difficult process but it is an essential requirement for producing good quality blends. The process very often is performed by a computer and combined with weigher or metering controls. There are basically two types of formulations:

1. grade formulas in which the nutrient guarantees are expressed as percentage of the total weight
2. and Soil test formulas in which the nutrient contents are calculated so that the blend produced will supply a certain amount of nutrients per acre when applied at a given rate. These are also called "Custom Blend" formulas.

Records should be kept of each formulation and this can be simplified by the use of a standard format in the computer.

For accurate formulation the actual raw material analyses should be used but standard analyses are helpful as a first approximation.

10.1 TO CALCULATE A GRADE FORMULA

a. Select materials. Material names and guarantees are given in Section J. Appendix 1.
b. Check material analyses
Be sure that the material guarantees used in formula match the guarantees of the material in the bin. For example, is the material actually DAP (18-46-0) or is it MAP (11-52-0)?
c. Specify the grade and perform the calculations

Example 1: Grade formulation
To determine the amount of individual fertilizer in a mixture, the quantity is calculated as follows.

$$\text{Quantity} = \frac{\text{(Percentage of plant nutrient desired in the mixture)} \times \text{(Weight of final mixture)}}{\text{(The Percentage of the plant nutrient in the straight fertilizer)}}$$

$$A = \frac{R \times T}{P}$$

R = Percentage in the mixture
T = Final weight of the mixture
P = Percentage in the straight fertilizer.

To prepare a mixture of 10: 5: 10 using $(NH_4)_2SO_4$, (20% N), Super phosphate (16% P_2O_5) and muriate of potash (60% K2O), the following quantities will be required per tonne (1,000 kg).

1. Ammonium sulphate = $\dfrac{10 \times 1000}{20}$ = 500 Kg.

2. Super phosphate = $\dfrac{5 \times 1000}{16}$ = 312.5 Kg

3. Muriate of potash = $\dfrac{10 \times 1000}{60}$ = 166.5 Kg

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Total = 979.0 Kg

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Filler = 1000 – 979 = 21 Kg.

If the total calculated weight exceeds the final weight, a mixture of that ratio can not be prepared.

NOTE:
Formulations containing less than 5% of any ingredient should be avoided as there will be difficulties in mixing this small amount evenly throughout the mixture.

Other approaches for calculating grade formula:
.**Example 1: A simple Grade formula**
A simple grade formula:
Calculate a 9-23-30 grade formula. The materials to be used are DAP (18-46-0) and Muriate of Potash (0-0-60).

Calculations:

1. Determine the amounts of each nutrient needed.

Method:
Kkilograms of a nutrient needed = formula weight in kilograms x nutrient guarantee (expressed as a decimal). Remember, formulas are calculated to have 1002 kgs
Then:

Nutrient	Percent required	Amount required in kg
Nitrogen	9%	1002 x 0.09 = 90.18; round down to 90
Phosphorus	23%	1002 x0.23 = 230.46; round down to 230
Potash	30%	1002 x 0.30 = 300.6; round down to 300

2. This can also be calculated using units.

Method:

One Unit = One per cent and is based on a 1002 kgs formula thus it equals 10 kgs. Nutrient requirements expressed as a percentage equals nutrient requirements expressed as units. Thus, units multiplied by
10 kgs of nutrient are needed for one tonne of product.

Example: nitrogen requirements are 9.0% or 9 units.
Amount of nitrogen in kgs needed = 9 x 10 kgs = 90.18 = 90 kgs.

3. Determine the amounts of each material needed to supply these amounts.

Method:
Nutrient requirement in kgs divided by the nutrient content of the material (expressed as a decimal) equals the kgs of the material required.
Then: Nitrogen and phosphate will be obtained from the DAP.
Nitrogen: 90 kgs required / 0.18 N in DAP = 501 kgs of DAP required.
Phosphate: 230 kgs required / 0.46 P2O5 in DAP = 501 kgs of DAP required.
Potash will be obtained from the Muriate of Potash: 301 kgs required / 0.60 K2O in Muriate = 501 kgs of Muriate of Potash.

4. Checking:
Total weight: 501 + 501 = 1002 kg
Nutrients:

Nutrient	Kilograms need
Nitrogen	90
Phosphorus	230
Potash	300

5. To double check that the percentage guarantee is correct, divide the total pounds of each nutrient by 2204 and then multiply by 100 to convert to per cent.
Example: Nitrogen: 198.4 / 2204 = 0.09 x 100 = 9.0
A completed calculation sheet would look like the following table for pounds:

Weight	Material	N	P2O5	K2O
501	DAP (18-46-0)	90	230	300
501	MOP (0-06-60)	90	230	300
1102	% (Per cent	9.00	23.00	30.00

To produce a tonne of this blend put 501 kgs of DAP and 501 kgs of Muriate of Potash into the blender. To make a 500 gram sample batch for use in a view box observation test weigh up 250 grams of each material.

Example 3: Grade formulation
Calculate a 17-17-17 blend using Ammonium Nitrate (34-0-0), DAP (18-46-0), Muriate of Potash (0-0-60), and Filler (0-0-0) if necessary. Remember the numbers in the brackets represent the Nitrogen, P2O5 and the K2O guarantees.
Calculations:

1. Determine the kilograms of each nutrient needed:
All 3 nutrients are guaranteed at 17.0 % or 17 units.
Using the unit method: 17 units x 10.01 kg per unit = 170.5 kg
Using the percentage method: 1001.8 kgs x 0.17 = 170.5 kgs each

2. Select the nutrient requirement to be calculated first
<u>Please note</u>: that the ratio of the phosphate to the nitrogen in DAP is 46 to 18 or 2.56 while the ratio in the formula is 1 to 1 or 1.0. If the P/N ratio in the formula is less than 2.56 and DAP is to be used, phosphate is the limiting factor and has to be calculated first. If it is greater, nitrogen is the limiting factor and is calculated first. The P/N ratio method can be used for any material containing nitrogen and phosphate. For example, the P/N ratio for MAP (11-52-0) is 52 to 11 or 4.73 (52/11 = 4.73).

3. Select the materials to be calculated first:
The amount of any material that supplies only one nutrient and that will not be used in combination with other materials should be calculated first. This is because often it is necessary to know the amount of room remaining in the formula before the final calculations can be made. Therefore, calculate the amount of Muriate of Potash required first, then the DAP, next the Ammonium Nitrate, and last the filler.

Then:
Potash: 170.5 kgs required / 0.60 K_2O in Muriate = 284.1 kgs of Muriate Potash
Phosphate: 170.5 kgs required / 0.46 P_2O_5 N in DAP = 370.1 kgs DAP (rounded up)
Nitrogen: Supplied from DAP: 370.9 kgs x 0.18 (N in DAP) = 66.8 kgs
Needed from Ammonium Nitrate: 375 - 147 = 228 lbs. (or 103.6 kgs)
Amount of Ammonium Nitrate required:
103.6 kgs required / 0.34 N in Ammonium Nitrate = 305 kgs (Roundedup to)

4. Determine if filler is needed and if so how much:
284.1 kgs Muriate + 370.9 kgs DAP + 103.6 kgs Ammonium Nitrate = 758.6 kgs.
1002 kgs total formula weight - 870.9 kgs nutrient material = 130.9 kgs of filler are needed. The completed calculation sheet would look like the following table:

Weight (kg)	Material	N	P_2O_5	K_2O
284.1	MOP 0-0-60			170.5
370.9	DAP (18-46-0)	66.7	170.6	
305	Ammonium Nitrate (34-0-0)	103.7		
130.9	Filler (0-0-0)			
1001.8	Total kg	170	170	170
	Percent (%)	17.01	17.03	17.01

10.2   Formula based on soil test

General:
The nutrient requirements that must be met by this type of formula are usually determined by testing the soil in which the crop is to be grown for the existing nutrient levels and then

comparing these levels to those necessary to grow the crop. The additional nutrients needed are then calculated and applied as a fertilizer mixture. After the nutrients have been determined, the formula calculations are first made on the basis of one acre and then converted into a tonne basis.

Example 3: Soil test formulation
The customer's soil test recommendation calls for the following application per hectare: He wants 40.5 hectares fertilized.
Nitrogen 145 kgs as N
Phosphate 134 kgs as P_2O_5
Potash 201 kgs as K_2O
Water Soluble Magnesium 22 kgs as WS Mg
Sulphur (Minimum) 34 kgs as S
Zinc 6 kgs as Zn
He has decided to apply 16 kg of nitrogen as a "side dresser" at a later date and to obtain the rest of the nutrients from one application of a fertilizer mixture.
Problem:
Calculate:
A. The materials required to fertilize one hectare.
B. The application rate per hectare.
C. Analysis of the mixture.
D. The materials required to make one tonne of the fertilizer.
E. Tonnes of the mixture required.

Calculate the materials required to fertilize one acre:
1. Materials Available:
DAP, Urea, Ammonium Sulphate, and Muriate of Potash, Sulphate of Potash-Magnesia (SPM) and Zinc Sulphate. The analyses of Sulphate of Potash-Magnesia are 22% K_2O, 11% WS Mg and 22% S. The analysis of the Zinc Sulphate is 36% Zn. Disregard the Sulphur content.

General Calculation Method:
First, calculate the materials needed to fertilizer one acre. All other information required can be calculated from this data. Since a specific amount of SPM must be used, it will have to be calculated first. The SPM will supply all of the WS Mg required and part of the Potash and Sulphur.

2. Materials Required:
Amount of sulphate of Potash-Magnesia needed to supply 22 kgs WS Mg:
Water Soluble Magnesium (WS Mg): 22 kgs required / 0.11 (WS Mg in SPM) = 200 kgs SPM
Sulphur (S) supplied: 200 kgs SPM x 0.22 S = 44 kgs S
Potash (K_2O) supplied: 200 kg) SPM x 0.22 K_2O = 44 kgs K_2O
Note that the minimum sulphur requirement has been fulfilled.
Amount of Muriate of Potash needed to supply the additional K_2O:
Potash:
Total needed: 201 kgs
From SPM 44 kgs
Additional needed 157 kgs
Muriate of Potash required: 157 kgs K_2O needed / 0.60 K in Muriate = 261 kgs

3. Determine whether to calculate the nitrogen or the phosphate requirement first: The P/N ratio of the nutrients is 145/(134-16) = 120/118 = 1.22. This is less than the DAP ratio of 2.56. Therefore, the phosphate requirement has to be calculated first.

4. DAP required to supply 134 kgs phosphate: 55 kgs / 0.46 P in DAP = 291 kgs

Nitrogen supplied by the DAP: 291 kgs DAP X 0.18 (N in DAP) = 52 kgs

5. Nitrogen:
Since the sulphur requirement was filled by the Sulphate of Potash-Magnesia, Urea, can be used to supply the rest of the nitrogen.

Urea required to supply the additional Nitrogen required:
Total nitrogen per acre needed: 145 kgs
To be obtained from "Side Dressing": 16 kgs
Nitrogen obtained from DAP: 52 kgs
Balance required: 77 kgs

Amount of urea required: 77 kgs required / 0.46 N in Urea = 167 kgs

6. Pounds of Zinc Sulphate needed to supply 6 kgs of Zn.
6 kgs required / 0.36 Zn in Zinc Sulphate = 17 kgs

Material	Weight (kg)	N	P$_2$O5	K$_2$O	WS Mg	S	Zn
Urea	167	77					
DAP	291	52	134				
MOP	261			157			
SPM	200			44	22	44	
Zn Sulphate	17						6
Totals and required	936	129	134	201	22	44	6

b. Application rate per acre:
Since the amount of each nutrient in the calculated mixture equals the amount requested, the calculated weight of 936 kgs will have to be applied per hectare.

c. Calculate the analysis of the mixture:
Method:
The kilograms of each nutrient in the mixture divided by the kilograms to be applied per acre multiplied by 100 gives the per cent of each nutrient in the formula.
The calculation is shown here for pounds only.

Nutrient	kg	Div		% Nutrient
N	129	936	X 100	13.78 % Nitrogen
P2O5	134	936	X 100	14.32 % Phosphorus
K2O	201	936	X 100	21.47 % Potassium
WS Mg	22	936	X 100	2.35 % WS Magnesium
Sulphur	44	936	X 100	4.70 % Sulphur
Zinc	6	936	X 100	0.64 % Zinc

d. Calculate the materials required per tonne of fertilizer:

Method:

Determine the conversion factor by dividing 1102 kg formula weight by the pounds per hectare. Then multiply the weight for each material per acre by this factor. Therefore, the factor is: 1102 / 936 = 1.177.

Material	Kg/ac.	Factor	Kgs/tonne
Urea	167	X 1.177	179
DAP	291	X 1.07	311
MOP	261	X 1.07	279
SPM	200	X 1.07	214
Zn Sulphate	17	X 1.07	18
Total	936	X 1.07	1002

e. Calculate the tonnes of the mixture required:

Method:

The number of acres to be fertilized multiplied by the pounds per acre to be applied divided by 1002 equals the tonnes needed.

Calculation:

(40.5 acres x 936 kgs) per ha) / 1002 kgs = 37.8 tonnes needed

11.0   REFERENCES

1.   CEN, European Standard /A1. Test Sieving (2003)

2.   CEN, European Standard EN 1236. Determination of bulk density (loose)

3.   CEN, European Standard EN 1237. Determination of bulk density (tapped)

4.   CEN, European Standard EN 12047. Measurement of static angle of repose

5.   CEN, European Standard EN 13299. Determination of the flow rate

6.   CEN, European Standard EN 12944 Vocabulary Part 1, Part 2 and Part 3

7.   CEN, European Standard EN 1482. Sampling Parts 1 & 2

8.   National Fertilizer Quality (Control) Act 2019

9.   NIS 106 – 9: 2018 - *Standard for Fertilizers: Part 9 - Methods of Analysis of Fertilizers*

10.   NIS 106 – 10: 2018 - *Standard for Fertilizers: Part 10 - Methods of Sampling Fertilizers*

11.   NIS 106 – 11: 2018 - *Standard for Fertilizers: Part 11 – Requirements for Packaging and Labeling of Fertilizers*

12.   NCP 24: 2009 - *Code of Practice for Handling and Storage of Fertilizers*

13.   Stairmand C J, The screening and Segregation of Fertiliser Materials. Proc. Fert. Soc. N°74, November 1962