Ministry of Food & Agriculture

PLANT PROTECTION & REGULATORY SERVICES DIRECTORATE

MINISTRY OF FOOD & AGRICULTURE GHANA

GHANA FERTILIZER BULK BLENDING GUIDE

Guidelines For The Production of Quality Fertilizer Blends In Ghana

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Acknowledgements

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– Mr. Eric Bentsil Quaye,

Director (Acting) Ministry of Food and Agriculture Plant Protection and Regulatory Services Directorate

Footnote:

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Acronyms

AP: Ammonium phosphate
AGRA
ATM: Atmosphere/atmospheric
B: Boron
Ca: Calcium
CBN: Central Bank of Nigeria
CIF: Cost in Freight
CRH: Critical relative humidity
Cu: Copper
DAP: Diammonium phosphate
DPC: Damp-proof course
EDTA: Ethylene Diamine Tetra Acetic Acid
EBITDA: Earnings Before Interest, Tax, Depreciation and Amortisation
ECOWAS: Economic Community of West African States
EFBA: European Fertilizer Blenders Association
EIA: Environmental Impact Assessment
EMP: Environment Management Plan
EPCM: Engineering, Procurement, Construction and Management
Etc: et cetera
Fe: Iron
FF: Fertilizer factor
GSI: Granulometric Spread Index
HQA: Holistic Quality Approach
IFDC: International Fertilizer Development Centre
ISFM: Integrated Soil Fertility Management
K: Potassium
LI: Legal Instrument
Mg: Magnesium
Mn: Manganese
Mo: Molybdenum
MOP: Muriate of potash
MSDS: Material Safety Data Sheet
N: Nitrogen
NPV: Net Present Value
P: Phosphorus
PMBOK: Project Management Body of Knowledge
PPE: Personal Protective Equipment
PPM: Parts Per Million
PPRSD: Plant Protection and Regulatory Services Directorate
RM: Raw materials
RP: Rock phosphate
RR: Recommended rate
RSSF: Real Sector Support Facility
S: Sulphur
SGN: Size Guide Number
SHERQ: Safety, Health, Environment, Risk and Quality
SOP: Sulphate of potash
SSP: Single superphosphate
TSP: Triple superphosphate
UEMOA: West African Economic and Monetary Union (Union Économique et Monétaire Ouest Africaine)
UI: Uniformity Index
YR: Year
Zn: Zinc

Binder – Material sometimes added to a blend to aid in preventing segregation.

Complete fertilizer – A fertilizer raw material that contains more than two nutrients, usually the three macronutrients: nitrogen (N), phosphorus (P), and potassium (K). They are physical mixtures of fertilizer raw materials containing the three main plant nutrients prepared through a bulk blending process.

Conditioners – For soils: products added to soil to improve the soil's physical qualities, usually its fertility (ability to provide nutrition for plants) and sometimes its mechanics. In general, these can be categorised as soil amendments (or soil improvers), which include a wide range of fertilizers and inorganic materials (SSSA, 2012). For fertilizers: substances added to enhance the physical condition of fertilizer mixtures and also reduce the hygroscopic nature, e.g. peat, groundnut shell, or paddy husk.

Countries in the Economic Community of West African States (ECOWAS) – Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

Holistic Quality Approach (HQA) – A fertilizer bulk blending approach that encompasses the various sets of procedures adopted by each of the 15 countries of ECOWAS and synchronises them into one.

Fertilizer – Any substance that is intended to be used as a nutrient(s) source to the crops for increasing agricultural production (ECOWAS Regulation C/REG. 13/12/12). Organic and mineral substances are utilized to ensure proper plant nutrition and supplement the nutrients already available in the soil, which are essential for plants to grow, thrive, and be healthy (IFA, 2020).

Fertilizer grade – Percentage content of total N, available P (phosphoric acid), and soluble K (Potash), e.g., 20-10-10, 15-15-15, and 27-13-13.

Fertilizer raw materials (RM) – These are inorganic sources of one or more of the essential nutrients required by plants for growth. They are required for preparing blended fertilizers.

Fertilizer requirement (FR) – (Recommended Rate [RR] / % Nutrient Content [NC] in Fertilizer Raw Material RM) * 100 * Area (ha), where 100 represents the reduced weight of the fertilizer raw material to 100 kg.

Filler – Materials added to fertilizers to help in the uniform distribution of nutrients within a given volume of the fertilizer product.

Guarantee – The minimum amount of nutrient content contained in fertilizers raw materials or fertilizer blends, expressed as a percentage. Excluding phosphorus (P2O5) and potassium (K2O), this is expressed in simple element form, e.g., sulphur (S). But for chlorine (Cl) content, the guarantee should not be more than the amount shown, e.g., 46-0-0, 18-46-0, or 0-0-60.

Micro nutrient – Any of the following nutrients that is essential for the normal growth of plants and that may need to be added, in smaller quantities, to the growth medium: boron (B), Cl, cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), sodium (Na), and zinc (Zn).

Mineral nutrients – Nutrients whose sources occur in soils.

Neutralisers – Substances added to counteract the acidity or basicity of soils or fertilizers, e.g., dolomitic limestone (basic) is added to ammonium sulphate (acidic) mixed fertilizers (Kostiner Edwards, 1992; Shakhashiri Bassam Z, 1989).

Nitrogen (N) – This can be considered to be the most important nutrient. It makes plants grow big and strong and is also known as the "green up" nutrient.

Definitions

Nutrient – Essential elements required by plants to make their own food through photosynthesis so they can grow. Essential nutrients are those required in varying quantities: N, P, K, Ca, Mg, S, F, Cu, Mo, and B.

Percentage nutrient content (NC) – Percentage quantity of each fertilizer nutrient in a fertilizer raw material.

Phosphorus (P) – This is the nutrient that is crucial in all reproductive phases of a plant, e.g., seeding, fruiting, flowering, and blooming phases. Thus, it is known as the "blooming" nutrient.

Potassium (K) – This nutrient is key to plants in that it regulates their activation of enzymes and the uptake of carbon dioxide and water. It aids the plants to build strong and healthy seeds and stems. Hence it is also known as the plant "photosynthesis" nutrient.

Primary nutrient – Any plant food such as nitrogen (N), available phosphoric acid P_2O5, and soluble potash K_2O or potassium (K).

Recommended rate (RR) – Quantity in weight of fertilizer nutrients to be applied in the soil as recommended by an agronomist or soil expert or as determined by a soil test analysis. In other words, it is the total NPK expressed on a kilogram per hectare (kg/ha) basis. This recommendation is based on crop requirements, soil fertility, soil texture, and planting season.

Secondary Nutrient – Any of the following nutrients that is essential for the normal growth of plants and that may need to be added to the growth medium: calcium (Ca), magnesium (Mg), and sulphur (S).

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

Single element fertilizer – A fertilizer raw material that contains only one nutrient, usually one macro nutrient, e.g., urea (46% N), single superphosphate (16% P_2O5), muriate of potash (60% K_2O), or sulphate of potash (50% K_2O), and may contain some micro nutrients. Also called a straight-element fertilizer.

Unit of recommended rate – Amount of fertilizer required per area, usually expressed per hectare.

Foreword

The Part III of the Plants and Fertilizer Act, (2010) Act 803 and its accompanying Regulations, Plants Fertilizer Regulations, 2012 (L.I.2194) gives PPRSD the mandate to regulate fertilizer importers, manufacturers, blenders, distributors and retailers. The fertilizer sector over the past decade has seen a number of reforms which has resulted in the expansion from a purely import-driven sector to the blending of inorganic fertilizers and production of organic fertilizers. There are plans for the country to be a manufacturer of inorganic fertilizers in the near future. The sector has over the past few years seen the setting up of six (6) blending facilities in the southern part of the country.

The operations of the blending facilities support the Government's drive to make available to farmers soil/crop-specific fertilizer formulas based on the soil/nutrient requirements. The PPRSD, which is the national regulator of fertilizer, has put in place a number of interventions to guarantee the quality of fertilizers through the empowerment of its fertilizer inspectors, the creation of awareness and the development of the capacity of stakeholders within the fertilizer sector.

Over the years, a number of these documents have been developed to guide the implementation of the Act and its Regulation. These include Analytical and Inspection Manuals and most recently Guidelines for the organic fertilizer sector.

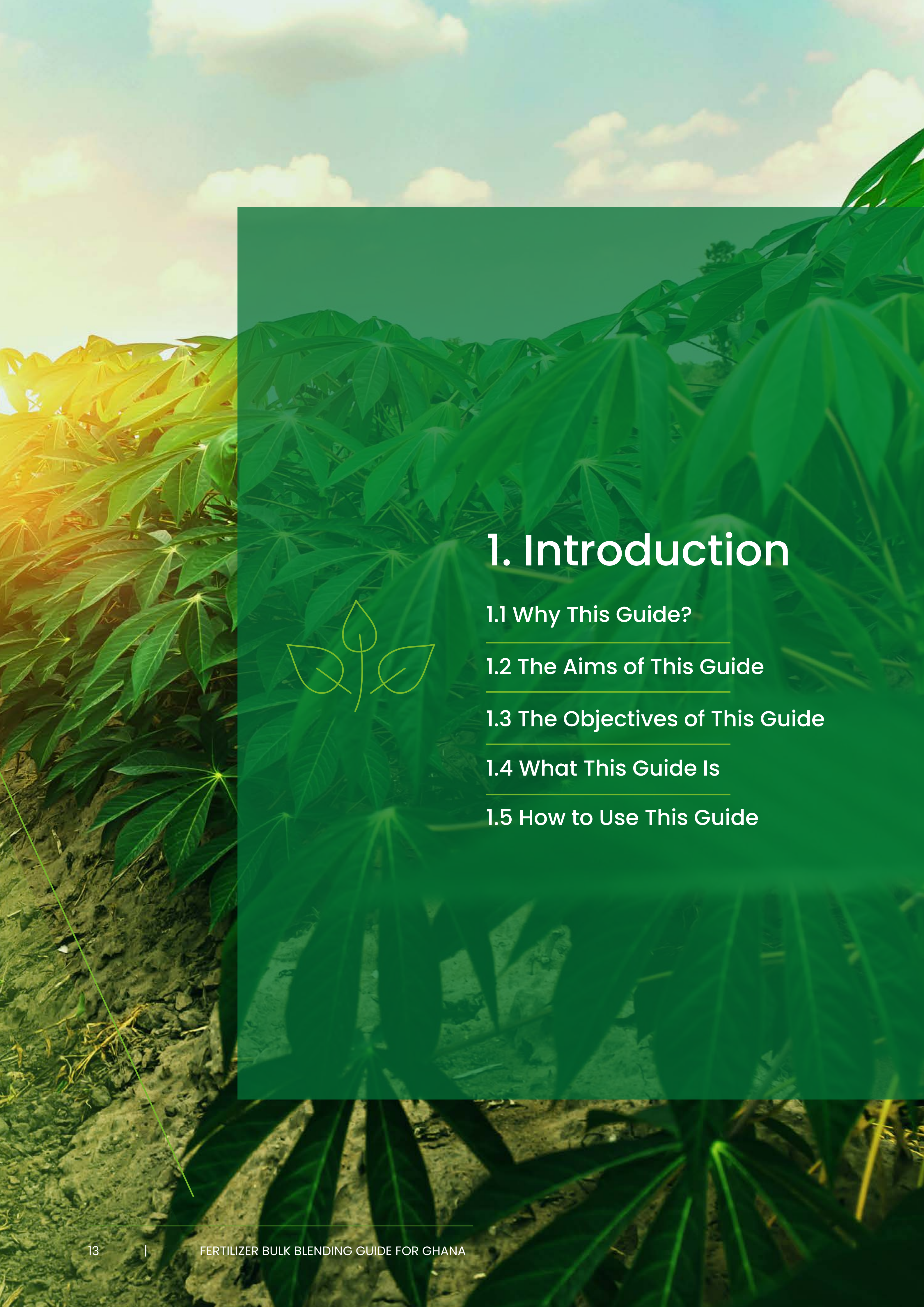
With the expansion of Inorganic Fertilizer use and particularly the developments in the blending of customised formulas, it has become imperative to set benchmarks to regulate the sector. Research has shown that bulk blends have associated quality issues, particularly with nutrient deficiencies and segregation as a result of the blending process.

As a result, there is a need for a guidance document to harmonise and set benchmarks for the procedures for producing quality blends and improve on the blended products delivered to farmers to increase productivity thereby closing the yield gaps currently being experienced in Ghana. The guideline covers; The Site and Raw Materials Selection for Bulk Blending; Storage and Dispatch of Blended Products; Accounting and Record Keeping as well as Quality Control of Blends.

This guideline is to be used as a source document to help the existing and future blenders to produce quality blends that will support the agricultural productivity of the country.

– Dr. Owusu Afriyie Akoto,

Hon. Minister Ministry of Food and Agriculture



1. Introduction

1. Introduction

Sixty percent (60%) of the total land area of Ghana is suitable for agricultural production, however, a significant portion is inherently low in fertility. This is primarily due to the highly weathered nature of soils across all agro-ecological zones in the country leading to high levels of nutrient leaching. The low fertility levels are exacerbated by low fertilizer applications and unsustainable agricultural and environmental practices. Extensive areas of the country's land area particularly have suffered from severe soil erosion and land degradation in various forms.

The soil nutrient depletion rates in Ghana are projected as 35 kg N, 4 kg P and 20 kg K ha-1. The extent of nutrient depletion is widespread in all the agro-ecological zones with nitrogen and phosphorus being the most deficient nutrients. Nutrient removal from soils by crop harvest is not replaced with corresponding amounts of plant nutrients in the form of organic and inorganic fertilizers. Crop yields suffer as a consequence and currently, average yields of most crops are 20-60% below their achievable yields indicating an urgent need to increase soil fertilisation, through Integrated Soil Fertility Management (ISFM) to ensure sustainable food production.

Due to the specific nutrient needs of soils and crops across the agro-ecological zones in Ghana, fertilizer bulk blending has in recent times become a key part of efforts to meet these needs.

Dominated by the private sector, the fertilizer bulk blending industry has seen tremendous growth in the country with an average growth of approximately 70% in production capacity over the past decade. There was therefore the need for collaboration between the regulatory agency, PPRSD and industry players to develop this set of guidelines to ensure that the quality of fertilizer blends produced in the country is not compromised.

1.1 Why This Guide?

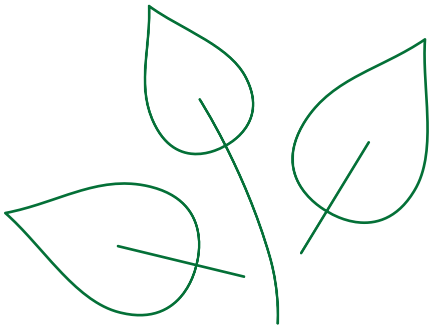
The rising claims of the lack of integrity of fertilizer blends in the region triggered a joint ECOWAS, the West African Economic and Monetary Union (UEMOA), and International Fertilizer Development Centre (IFDC) study assessing the quality of fertilizer traded in West Africa, including factors influencing fertilizer quality in the region.

This study was carried out between 2010 and 2013. The findings revealed several quality issues of blended fertilizer in the region:

- Underweight bags are common.
- The quality of the same bulk blend formula varies among blenders.
- Insufficient nutrient addition during blending operations is the major cause of nutrient shortfalls in blended products.
- The physical characteristics of fertilizer raw materials directly impact the quality of blended products.
- NPK blends present more cases of poor product quality than NPK compounds.
- Segregation is a major issue for blend quality but has a minimal effect on the shortfalls of nutrients in blended products.
- Adulterated blended products are minimal.

The assessment results listed above are similar to the ones found in Ghana. For instance, the sale of underweight bags is estimated to occur in 12% of the fertilizer bags traded in the country and the nutrient shortages in some of the bulk blend fertilizers are considered cases of adulteration when the nutrient shortage is deliberate.

These findings necessitated the need for a blending guide, comprising a harmonized set of blending practices, to be created for adoption by blending operators across West Africa.



1.2 The Aims of This Guide Are To:

- Give the blenders the information needed to produce quality blended fertilizer grades that meet Ghana's regulatory requirements.
- Increase awareness and encourage participation of all relevant stakeholders to ensure its use across the country.

1.3 The Objectives of This Guide Are To:

1

Ensure proposed guidelines agree with stakeholders' realities.

2

Ensure strict adherence to the guidelines with current fertilizer regulations in Ghana.

3

Ensure alignment with best agricultural practices promoted as they relate to fertilizers.

4

Provide clear detailed guidelines of all the necessary procedures to ensure good quality blends, illustrated with colour pictures and graphs.

5

Provide templates for forms and technical documents that may be of use in applying the guidelines.

6

Provide clear and accessible references to the existing documentation and legislation referred to in the guidelines.

1.4 What This Guide Is

This guide for Ghana was derived from the regional fertilizer blending guideline for West Africa developed by IFDC. It discusses the steps required to produce quality fertilizer blends. The guide is divided into five sections. Each section represents a unique step in the process essential to achieving high-quality outputs.

Section 1

Explains what the guide is, why the guide came to be, how to use it, and the environmental parameters to consider when producing quality fertilizer blends.

Section 2

Details the entire bulk blending process from the beginning. It delves deep into how to produce quality fertilizer blends for new and existing operations and provides information on the quality control aspects of producing quality blends.

Section 3

Highlights guidelines for how to store and dispatch the blends produced so that the quality of the blends is not compromised.

Section 4

Explains the importance of record-keeping in the process of producing quality blends.

Section 5

Concludes with the important aspects of the guide and gives recommendations on how to produce quality blends.

1.5 How to Use This Guide

This guide is a reference tool that will assist bulk blending operators in producing quality fertilizer blends. It is to be used in conjunction with the Plant and Fertilizer Act, 2010 (Act 803) and the Plants Fertilizer Regulation, 2012 (L.I. 2194). The National Fertilizer Policy was also passed in 2013. These interventions were necessitated by the incidence of unfair competition among fertilizer enterprises and reported poor quality and underweighted products imported for distribution at the onset of the privatisation of the sector in the early 1990s.

The above-mentioned legislations provide for the safeguarding of the interests of farmers against fertilizer nutrient deficiencies, adulteration, misleading claims and short weight; the creation of an enabling environment for private sector investment in the fertilizer industry; protection of the Ghanaian environment and its population against the potential dangers associated with fertilizer use. The national regulation aligns with the ECOWAS regulation.

Therefore, consultation with the following documents and ECOWAS regulations is advised while using this guide:

- Each blending operator's internally developed set of standard operating procedures (SOPs).
- The technical manual of the blending plant provided by the manufacturer.
- The Ghana Fertilizer Analytical Manual
- The Ghana Fertilizer Inspection Manual

In addition, this guide is to be used in conjunction with the internationally accepted standards on the quality of fertilizer blends as stipulated by the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO). These normative references are not freely available but can be purchased by directly contacting the organisations.

Clickable Links

- EN 1235:1998 /A1:2003. Test sieving
- ISO 3944:1992. Determination of bulk density (loose)
- EN 1237:1998. Determination of bulk density (tapped)
- EN 12047:2002. Measurement of static angle of repose
- EN 13299:2002. Determination of the flow rate
- EN 1482-1:2007. Sampling and sampling preparation. Part 1
- EN 1482-2:2007. Sampling and sampling preparation. Part 2
- ISO 5306:1983. Fertilizers – Presentation of sampling reports
- ISO 5315:1984. Determination of total nitrogen content
- ISO 6353-1:1982. Reagents for chemical analysis. Part 1
- ISO 6598-1985. Determination of phosphorus content
- ISO 7409:2018. Marking, presentation and declarations
- ISO 8157:2015. Fertilizers and soil conditioners – Vocabulary
- ISO 17319:2015. Determination of water-soluble potassium content

2. Producing Quality Fertilizer Blends

2. Producing Quality Fertilizer Blends

Fertilizer bulk blending is the process of using an appropriate plant to mechanically mix at least two fertilizer raw materials that are compatible, of similar particle size, and with known nutrient contents. To produce quality fertilizer blends, attention must be paid to every aspect of the bulk blending operation because of the important role each plays in the final output of a quality fertilizer blend product.

Manufacturers of fertilizer raw materials have a duty to ensure that the quality of what they produce is up to specification. The raw materials must be compatible, suitably sized and the nutrient content guaranteed.

Blending operators are advised to utilise standard equipment and be flexible enough to deal with multiple blend scenarios. It is their responsibility to confirm the quality of the raw materials received, ensure blend quality, and properly maintain the plant.

Blending operators have a duty to consider environmental parameters, such as critical relative humidity, temperature, moisture content, weather, and climatic conditions of the site where the blending operations will take place.

2.1 Create A Business Plan

For a new operator, the first step is to develop a good business plan that details all the necessary inputs, such as the capital, development, and operational expenses, required to run a profitable operation. A profitable and well-run blending operation will most likely produce high-quality blended products.

The business plan should show the flow of raw material, human, and financial resources and profitability analysis for a period of approximately ten years. It should consider regional dynamics in the business environment, which will help optimise the operation.
A business plan helps in the business decision-making process, especially for new clients, whereby visible projections will help them decide whether to proceed with the investment.

A qualified consultant, preferably one who has experience in developing fertilizer bulk blending projects from scratch, should be contracted to prepare the business plan. Refer to Annex A for details of some key information that should be captured in a business plan and Annex B for indicative cost estimates required to set up a turnkey bulk blending operation.

Registration procedures for inorganic fertilizers blenders in Ghana

As prescribed under Section 68 of the Plants and Fertilizer Act, 2010 (Act 803), a person shall not import, manufacture, or distribute fertilizers in commercial quantities unless registered. Fertilizer entities after securing their Assembly and Factory Inspectorate Permits and EIA Reports can then proceed to the Ministry of Food and Agriculture to officially register to be a Blender.

The process for registration by MoFA-PPRSD is as:

1. An application letter to register as a Blender should be addressed to the Minister, Ministry of Food and Agriculture via this address: **P. O. Box M 37, Accra, Ghana**

2. The application should include all the fertilizer products to be blended. A brief description of the company's profile should be included in your letter of application.

The following documents should also be attached to the application letter:

- Certificate of registration of business,
- Certificate of commencement of business from the Registrar General's Department,
- Environmental impact assessment report,
- Approval permit from the district assembly where the plant is to be situated,
- The product Safety Data Sheet (SDS), and
- Certificate of Analysis (COA) should be included for verification purposes.

The minister shall acknowledge receipt of the application and within a stipulated period not more than two (2) months from the date of submission of the application, inform the applicant of the outcome of the decision:

- The applications (for blending and products) that satisfy all the requirements will be registered, while those that do not meet the requirements will be rejected. Blended products will only be registered based on a favourable report from testing in the laboratory and/or field.
- Reasons for the refusal of the application shall be communicated to the applicant in writing. The applicant may reapply for review within two (2) weeks of receipt of the letter.
- Registration certificate approved is not transferable.

Renewal of Certificate for Blending Companies and/or Products

1. Registration approved by the minister is subjected to renewal within specified years and the application for renewal shall follow the same procedure as the initial registration. The application for the renewal of registration should be submitted ninety (90) days prior to the expiring date.

2. A specified renewal fee shall be paid to MoFA/PPRSD.

3. The entity ceases to be a fertilizer blender upon failure to renew the registration of their company and/or their product as required, or if the renewal application is rejected by the minister. Applicants are therefore required to acquaint themselves with the registration procedures prior to application.

Registration Fees

Registration fee charges for various fertilizer entities are subject to periodic review. Refer to the current Fees and Charges Amendment Instrument for the approved registration fees.

NB: Registration of fertilizer blenders is valid for 5 years and renewable at half the initial cost of registration. Subsequent renewals are done every 2 years. Renewal of the product registration is after two (2) years and is half the original price.

2.2 Selection of A Site For The Bulk Blending Operation

The next step is to ensure the production facility is established at the best location. One of the major discussions around siting a blending operation revolves around whether it should be close to the ports or close to the farm areas where the blends are consumed. Table 1 lists some pros and cons of each situation.

Table 1. Siting An Operation At The Port Versus In-Country

BULK BLENDING OPERATION SITUATED WITHIN OR NEAR THE PORT	BULK BLENDING OPERATION SITUATED IN COUNTRY
Lower receipt time for raw materials imported by sea	Less expensive facility setup due to no extra port fees or charges
Less risk of double handling raw materials and finished products	Less risk of corrosion to steel components due to saltwater in the atmosphere
Lower cost of final blend products due to absence of transport and other costs	Can be closer to farmers, the final consumer of the blend products
Less need for storage of final blend products required due to quick dispatch times	Less susceptibility to major humidity issues
Large-scale bulk blending operations can be profitable	Small-scale bulk blending operations can be profitable
More expensive facility setup due to extra port fees and charges	Longer receipt time for raw materials imported by sea
Higher risk of corrosion to steel components due to saltwater in the atmosphere	Higher cost of final blend products due to addition of transport and other costs
Far from farmers or the final consumer of the blend products	More need for storage of final blend products required due to slower dispatch times
More susceptible to major humidity issues	Large-scale bulk blending operations may not be profitable
Small-scale bulk blending operations may not be profitable	

Source : Chinedu Ohanyere, 2022

2.2.1 Guidelines On Site Selection for Bulk Blending Operations in Ghana

As shown in the table, there are advantages and disadvantages for each situation. Therefore, no one plan fits all. To determine the best location, various trade-offs, such as the client's preference and financial capability, availability of suitable or preferred site, and environmental, social, and governance factors, will have to be made. In general, siting a blending operation consists of three components: site selection, facility construction, and plant selection.

The selection of site(s) for bulk blending of inorganic fertilizer production facilities should be carried out within the existing legal framework of Ghana. Due to the associated environmental, economic, social and cultural impacts of such facilities, there is a need for stringent regulatory measures to safeguard all actors. There are a number of Governmental Agencies that a potential Blender would have to engage and subsequently follow the guiding Regulations for the setting up of such facilities. These Agencies include the Plant Protection and Regulatory Services Directorate (PPRSD), Environmental Protection Agency (EPA), Factories Inspectorate Directorate and the Local Assemblies.

1

An experienced consultant, preferably one who has previous experience in developing fertilizer bulk blending projects from scratch, should assist in the site selection.

2

The site should be easy to locate, accessible by road and rail (when applicable), and located in a secure area; it should not be in or close to a residential area.

3

The operation should not be located near a body of water. If the site is quayside, within a port, all design regulations and parameters must be strictly adhered to.

4

An expert should conduct a sound environmental impact assessment and ensure adherence to the laws, policies, and regulations of the country.

5

Direct and indirect labour should be sourced from within the community.

6

An operator should get to know the neighbours, forging relationships with them for sustainable security practices.

2.2.1.1 Environmental Impact Assessment (EIA)

Applicability Projects likely to have significant impacts on the environment, including bulk blending facilities are required to follow the steps below, to obtain environmental permits from the EPA prior to construction and operation:

1. Steps In The EIA Process

a) Registration of the potential production facility with EPA

b) Screening of registration by EPA within 25 working days

c) Scoping reviewed and Terms of Reference agreed.

d) Developing of Environmental Impact Statement (EIS)

e) Award of Provisional Environmental Permit

2. Terms of Reference for the EIA (Approach to be taken/methodology)

a) Description of project

b) Analysis of the need for the project

c) Alternatives to the project

d) Description of the project site (why that site was selected/any alternative sites considered)

e) Identification of other existing environmental conditions (social, economic and environmental concerns)

f) Potential positive and negative impacts of the project on environmental, social, economic and cultural aspects

g) Potential impact on the health of the people

h) Mitigation measures and potential negative socio-economic, cultural and public health impacts on the environment

i) Plan for monitoring predictable environmental impact and proposed mitigation measures

j) Contingency plans to address unpredicted negative environmental impacts and proposed mitigation measures for these impacts.
k) Provision of an environmental management plan.

l) Consultation with the communities affected by the project

m) Proposal for payment of compensation for possible damage to land or property arising from the project

n) Maps, plans, tables, graphs, etc. to assist in understanding of the project

o) Indication of areas inside or outside Ghana that are likely to be affected by the activities of the project

3. Environmental Impact Statement

All possible direct and indirect impacts of the project on the environment at the pre-construction, construction, operation, decommissioning, and post commissioning phases must be included as follows:

a) Possible levels of concentration of pollution in the environment (air, land and water) from mobile or fixed sources by the project

b) Possible direct ecological changes from discharged pollutant concentration on communities, flora and fauna

c) Possible alteration in the ecology from the project

d) Possible noise and vibration levels

e) Possible odour nuisance levels

f) Impact of possible plant/equipment failure

g) Potential risk of occupational, health and safety to workers

h) Potential outburst or leakages of pipes carrying sewage to plant and its implications for groundwater

i) Impact of the project on vehicular traffic

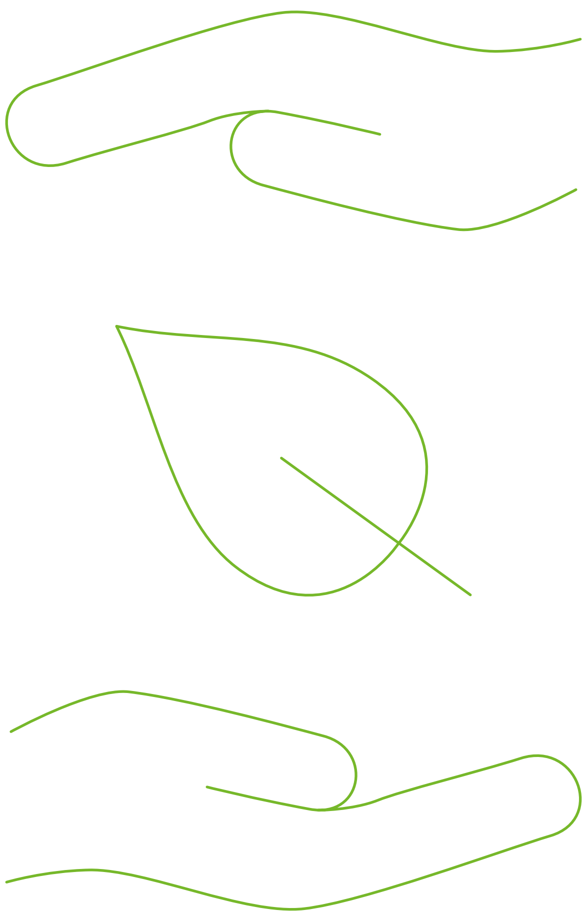
j) Possible health effects of the project on people within the project catchment zone

k) Possible changes to the social, cultural and economic patterns of the people within the project catchment zone

l) Possible land reclamation plan after decommissioning

4. Municipal/District Assembly Approval

The planning/projects work and housing department of the metropolitan, municipal or district assembly (MMDA), where the project shall be situated, shall give approval to the location of the project.



2.3 Select A Bulk Blending Plant

After selecting a suitable site, selection of a blending and bagging plant that meets modern mechanical, electrical, and instrumentation standards will ensure good quality blend products.

2.3.1 Guidelines On How To Select Bulk Blending Plants

To select and purchase the best equipment that will meet your specific requirements, it is important to know the following:

1) How much is the budget set aside for purchasing a plant?

2) What quantity of blends will be produced per annum?

3) What types of blends will be produced per annum?

4) How many types of primary, secondary, and micro nutrients will be used?

a) Which type of micro nutrients will be used (liquid, powder, or granules)?

b) Which other materials may be added to the blends, e.g., anti-dust or anti-caking agents, inhibitors, and bio-stimulants?

5) At what performance requirement should the plant operate?

a) What blending and bagging capacity should the plant have?

b) At what rate per hour should the plant blend (efficiency)?

c) How precise should the blends and bag weights be (accuracy)?

d) How flexible should the plant be with regard to multiple kinds of blend specifications and quantity requests?

6) Which operating system should the plant have: manual or automated?

7) What are the dimensions of the plant, so the space requirements within the facility can be determined?

8) What season(s) should the products be provided, e.g., rainy season farming, dry season farming, or both?

9) How will raw materials be stored in the warehouse – in bulk, in bags, or both?

10) Will the raw materials be conditioned, i.e., lump breaking, screening, etc.?

11) Will loading equipment be provided for blending and bagging operations, e.g., front-end loader?

12) What package sizes will be used for the finished product, e.g., 25 kg, 50 kg, 500 kg, 1,000 kg, or bulk?

13) How is the plant supplier's after-sales service?

a) Is there availability of in-country call out for service?

b) Is assistance available remotely from the source?

c) Are spare parts available in stock or through quick shipment?

14) Are local fabricators available for custom fabrications that may be required to adapt the plant to suit the environment and ensure a steady supply of common consumables and spare parts?

Refer to Annex C for the indicative cost of blending plants of various plant capacities.

2.3.2 Types Of Bulk Blending Plants

Bulk blending plants can be categorised as batch or continuous type. There are also the combined systems in which a setup consists of a combination of batch and continuous types.

- Batch-type plants
- Vertical auger blender type
- Horizontal drum blender types
- Paddle blender type
- Tower style blender type
- Continuous-type plants
- Continuous blender by weight control
- Continuous blender by volumetric control

The main difference between the two types is that the batch system is better for operators who wish to produce blends of different formulations in batches ranging from 1 to 14 tons and operate at a speed of no more than 70 metric tons per hour (mtph), while the continuous system is better for operators who wish to produce blends of the same formulation in large volumes at a time and operate at a speed of more than 70 mtph.

Annex D lists some major bulk blending plant manufacturers and Annex E provides illustrations of each type of plant. For safety issues concerning both types of plants and guidelines on how to handle them, refer to Section 2.9.3 on plant maintenance and safety.

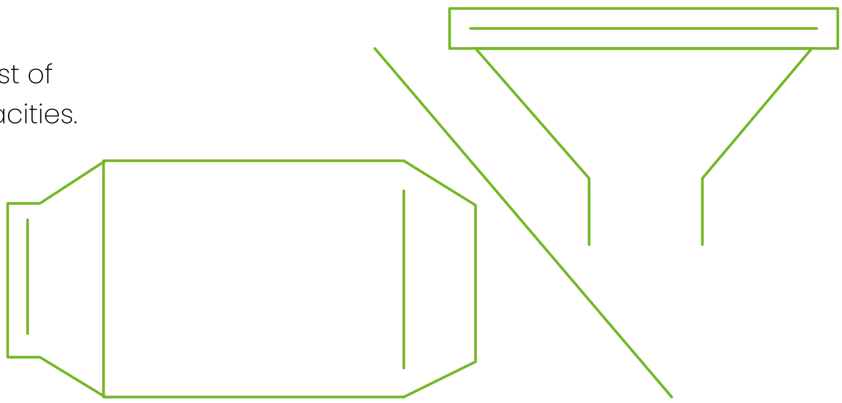


Table 2. Differences In Bulk blending Plants

BATCH BLENDING SYSTEM	CONTINUOUS BLENDING SYSTEM
Blends product recipes in batches ranging from 1 to 14 metric tons (mt) per batch.	Blends products continuously at thousands of metric tons per formulation.
Can be operated manually or with low-level software.	Always an automated system and uses a higher level of software to control material flow.
Maximum operational speed is 70 mtph.	Maximum operational speed can exceed 200 mtph depending on how quickly raw materials can be fed into the intake bins and if multiple bagging lines are used at once.
Blend cycle time can be easily adjusted, i.e., paused or slowed, especially when liquids are being used.	Blend cycle times cannot be easily adjusted because they are preset. The production cycle should not be interrupted.
Easily handles special blend formulas and very complex blends.	Success relies heavily on constantly feeding raw materials to meet the required production rate.
Easily handles powder and liquid micro nutrients.	Success relies heavily on free-flowing raw materials.
Easier setup for small capacities, therefore good for near or on-farm setup.	Easier setup for large capacities.
Tower-type systems can handle very high tonnages.	Can handle very high tonnages due to the possibility of multiple intake bins and bagging lines.
Layering and proportioning of ingredients is not required, so does not require layering software.	Requires layering and proportioning software for adjustment to reach balanced layering and proportioning of the ingredients.
Transfers ingredients to mixer at high speed.	Doses ingredients at once using automated rates. Transfers ingredients to mixer continuously.
Can be less expensive, except for the tower type.	Can be more expensive depending on the number of bins required for setup.
Can be more flexible in the amount of raw material that is used, depending on how the weigh hopper is being fed.	The amount of raw materials that can be used is limited to the number of intake bins or dosing units the system has and is configured for.

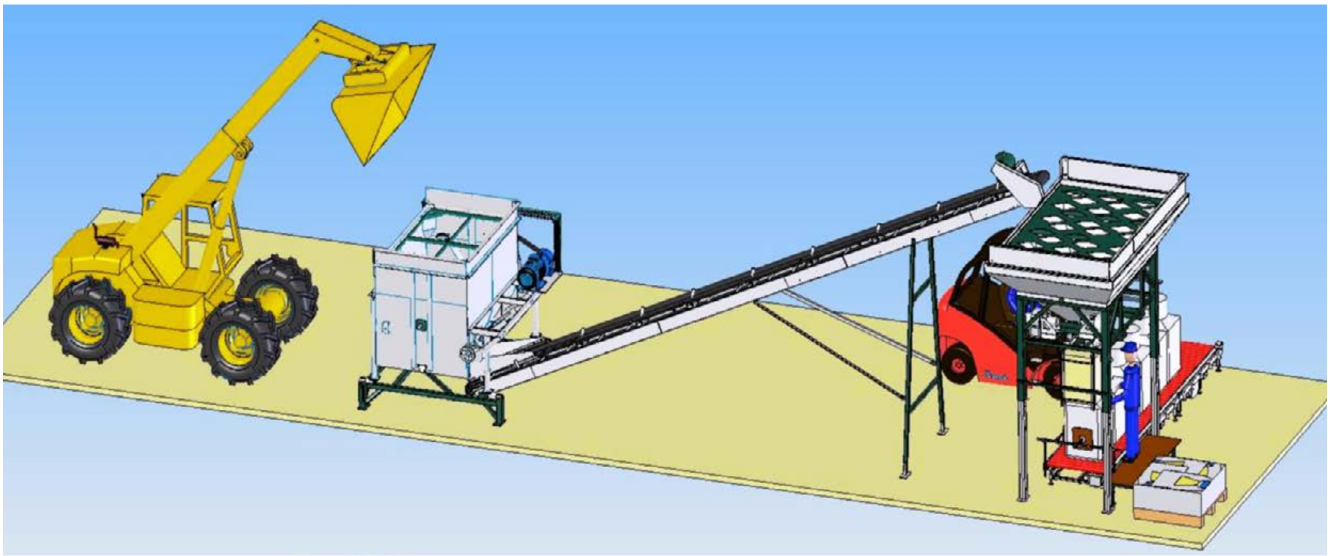
Source : Chinedu Ohanyere, 2022

2.3.2.1 Batch Bulk Blending Plant

This type of plant mixes fertilizer raw materials that flow freely, in batches, to create blends. It uses a hopper or a set of hoppers and a loss-in-weight system to do this. There are different types of batch systems that work in different ways, but in general, the following steps apply to all.

1. Establish the total quantity of blended products to be produced.
2. Divide the total quantity into batches.
3. For each batch, calculate the exact quantity of each raw material (primary, secondary, and micro nutrient[s]) required. *See Section 2.8 for examples.*
4. Fill the blender with the various raw materials that make up the formulation until the desired weight for each raw material is reached. This can be done from one weigh hopper, automatically from multiple weigh hoppers, directly with a loader, or another way.
5. When all the materials required are fed into the weigh hopper, start the blend time. Depending on the type of blender and the formulation, blending can take several minutes.
6. After the blend time is finished, the blender starts to discharge the batch. Blend discharge can be done in several ways, depending on the operation.
7. Start another batch only when the discharging of the previous batch is done and the blender is empty.
8. Repeat these steps until the required quantity of blended product is reached.
9. The batch time is the time between the start of filling the first time and the start of filling of the next batch.
10. The batch time and the capacity per batch depending on the overall capacity per hour of the blending unit.

Figure 1 : Batch Blending Plant



2.3.2.2 Continuous Bulk Blending Plant

This type of plant continuously mixes fertilizer raw materials that flow freely to create blends. It consists of multiple dosing systems that discharge the raw materials into a continuous blender. The blender is a continuous type in that it is filled on one side and automatically discharges on the other side; hence, the product flow can continue for an indefinite period. The raw materials are blended for a minute or less. The following are steps to operate this type of blending plant:

1. Establish the total quantity of blended product to be produced.
2. Break the total quantity into quantities of each raw material required for the blend.
3. For each quantity of raw material, calculate the exact quantity of each macro, secondary and micro nutrient raw material required.
4. Measure each raw material required based on its calculated weight and feed it into its designated hopper.
5. Feed all the raw materials required into their designated hoppers until they are full. Start the blending process. The plant should automatically start dispensing the products onto the under-bin conveyor, using the applicable discharge system, which feeds the blender.
6. Continue feeding raw materials into their designated hoppers.
7. Repeat these steps until the anticipated quantity of blended product required is reached.

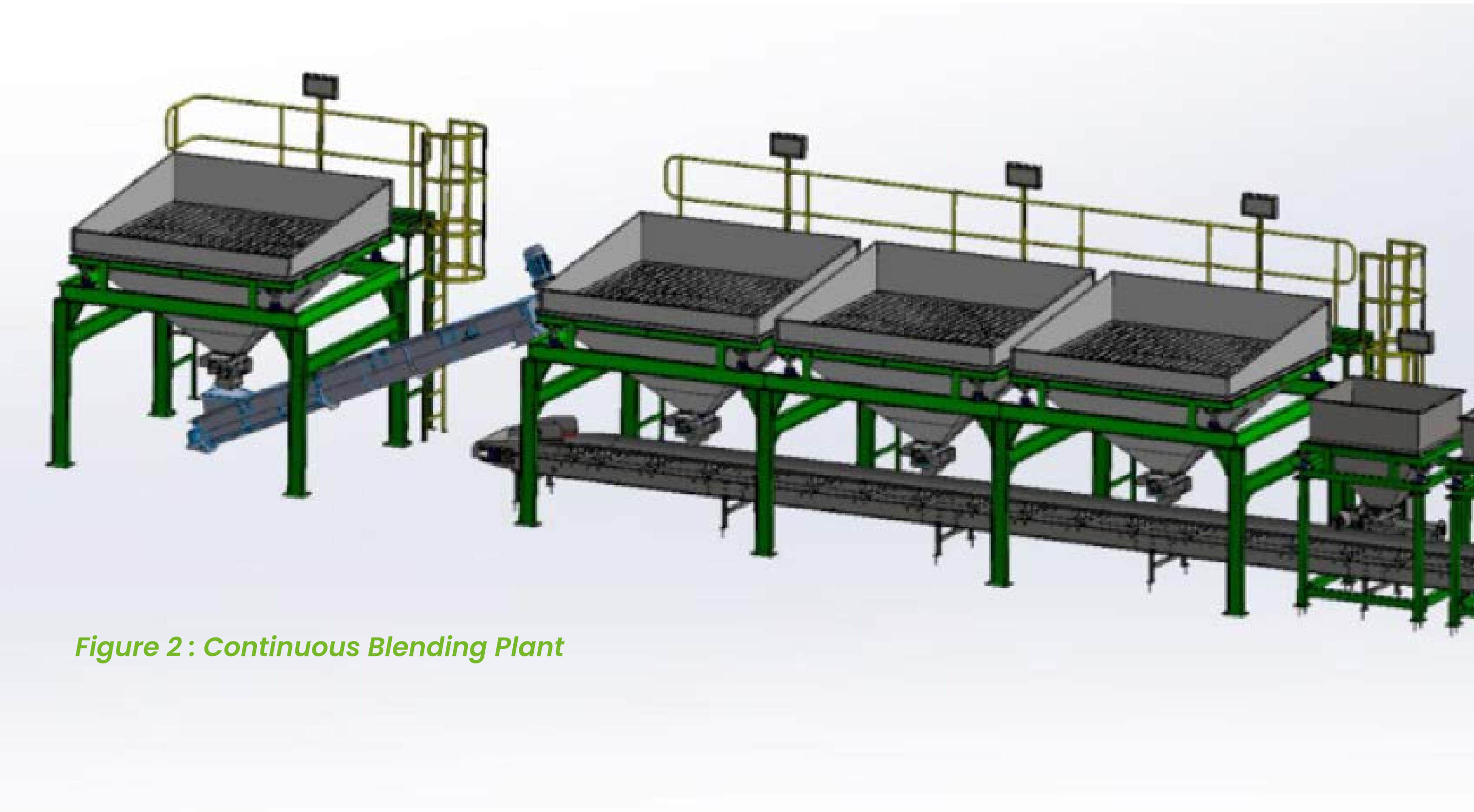


Figure 2 : Continuous Blending Plant

2.4 Construction Of A Bulk Blending Facility

When the type plant is selected, a new operator constructs a facility where the operation will take place. During the design and construction stages, the corrosive nature of fertilizer, the health and safety of personnel, raw material and finished product stewardship, transport equipment, and truck parking bays for clients should be taken into consideration.

For personnel safety, the facility should be able to withstand all structural loads. Leaking roofs, floors and pipes which are common features of poor construction, must be avoided as they can contaminate the raw materials. For the plant and mobile equipment, the floor design of the facility should be sized for a mix of structural stainless steel reinforcement and solid concrete. The facility should also be able to tolerate vibration.

2.4.1 Guidelines On How To Construct A Bulk Blending Facility

Consider the following guidelines when planning the construction of a bulk blending facility:

1. The factors influencing the cost of constructing a bulk blending facility include planned throughput per annum, planned throughput cycles per annum, market demand, client preference, and financial capability, among others. Throughput is defined as the quantity of raw materials passing through the production facility, i.e. an aggregation of raw materials received and produced blends dispatched.
2. The components of a facility include buildings (main warehouse, external buildings, etc.) and external works (truck parking bays for customers, warehouse loading bays where applicable, service buildings, etc.). Traffic management, for alleviating the nuisance that can be caused by traffic and truck flow, should be considered during the design stage.

3. Experienced engineering design and construction teams, preferably those from the country where the project is to be sited with local knowledge of the environment, and who have had previous experience in developing similar projects from scratch, should be contracted to design and construct the facility.
4. Reinforced concrete elements should be to the engineer's specifications. They should be of high-grade quality. Steel rods should be painted with anti-corrosion agents. The concrete mix and water ratio should be in accordance with the engineer's specifications. The mixture should have minimal water content to reduce issues of pore formation within the concrete. The concrete thickness between the steel rods and the edge must be a minimum of 50mm. The area should be cross-ventilated.
5. Structural steel elements should be to the engineer's specifications. They should be of high-grade quality and coated or painted with anti-corrosion agents.
6. Roof coverings should be to the engineer's specifications to prevent water leakage.
7. Mechanical and electrical installations, e.g. plumbing and wiring, should be to the engineer's specifications to prevent pipe leakage and fire outbreak.
8. Lighting within and outside the facility should be to the engineer's specifications. A bulk blending facility must be well-lit for safety and security reasons. For example, some raw materials are similar in colour, so a poorly lit facility could cause the wrong raw material to be used in a blend, resulting in low-quality or hazardous blend products. Good lighting will also help prevent accidents between man and machine. The space outside the facility should remain well-lit at night time.
9. A dust expeller must be incorporated into the facility in the plant area.
10. A temperature and humidity reader should be installed within the facility. These help in determining the critical relative humidity (CRH) of the environment, which plays a major role in the storage and use of fertilizer raw materials in bulk blending. Knowing the CRH also helps in determining the chemical compatibility of raw materials, which aids in the production of quality blend products.
11. The air quality in the facility must be checked to prevent certain reactions with the raw materials.
12. Annex F provides an example of an architectural layout of the internal spaces of a bulk blending facility. A full layout should include the components listed in item #2.
13. Annex B provides an indication of the cost of constructing bulk blending facilities of various throughput capacities and procuring raw materials for their operations.

2.5 Select A Blend Formula Approach

In Ghana, the following approaches are the most commonly used in delivering blend specifications to operators for production:

1. **Blanket Recommendation Approach:** This is the most popular approach in Ghana. It occurs when uniform fertilizer doses and applications are recommended across the board, e.g. for staple crops or primary cash crops.

2. **Crop/Site-Specific Research Approach:** This happens when blend specifications derived by research are issued by an agronomist, soil expert, or a qualified group.

2.6 Selection And Sources Of Raw Materials

The third step in producing a quality blend is to select the required raw materials. Key considerations in selecting raw materials include cost, chemical and physical compatibility, product stability, and availability. Poor-quality blends may be produced when poor-quality raw materials are used. The table below lists the characteristics of some common fertilizers and their nutrient content. The total quantity of raw materials required should be determined before sourcing and purchasing them.

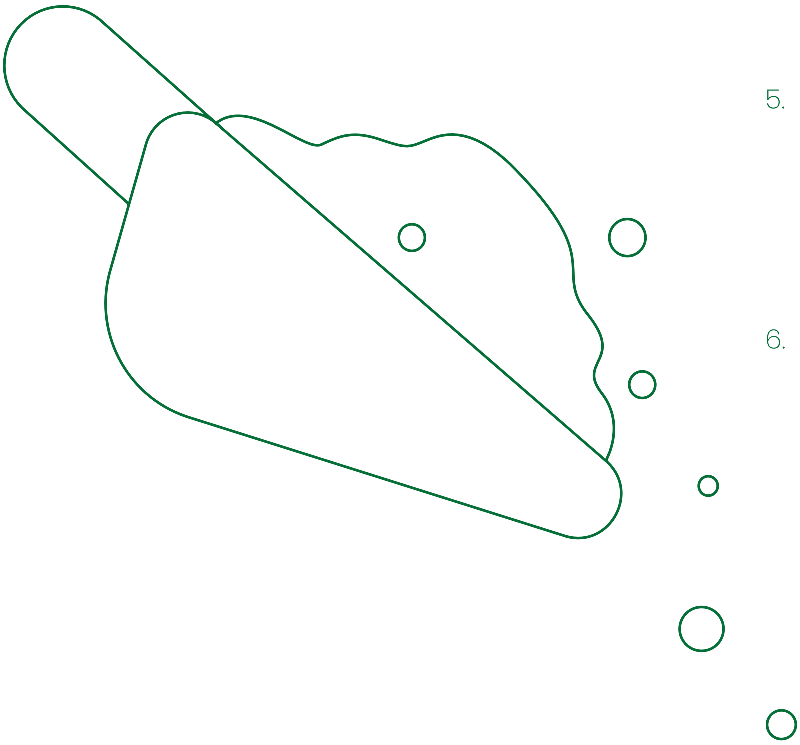
Table 3. Some common fertilizer raw materials and their nutrient contents

BLEND INGREDIENT	N	P_2O_5	K_2O	Ca	Mg	S	Zn	B	Cu	Cl
	----------------- Typical analysis, % -----------------									
Ammonium nitrate	34									
Urea	46									
Calcium Ammonium nitrate (CAN)	26-28			6-10	0-3					
Yara Amidas	40					5.6				
Ammonium Sulfate	21					24				
Diammonium Phosphate (DAP)	18	46								
Monoammonium Phosphate (MAP)	11	52								
Phosphate Rock (PR)		27-29		25-28						
Triple Superphosphate (TSP)		45-46		15		2-3				
Single Superphosphate (SSP)		16-20		18-21		7-9				
Muriate of Potash (also KCl, MOP)			60							45
Sulfate of Potash (SOP)			50			18				
Elemental Sulfur						80-100				
Polyhalite (Polysulfate®, POLY4)			14	12.1	3.6	19.2				
19-38-0+7S	19	38				7				
Gypsum (calcium sulfate dihydrate)				23		18.6				
Magnesium Sulfate monohydrate (kieserite)					15	19.8				
Zinc Sulfate Monohydrate						17	35			
Zinc Sulfate Heptahydrate						10	21			
Zinc oxide							70-80			
Borax Decahydrate								10		
Borax Pentahydrate								14.5		
Disodium Octaborate Pentahydrate								20.9		
Boric Acid								17.5		
Copper Sulfate Pentahydrate						12			25	
Cupric Oxide									60-80	
Cuprous Oxide									75-89	
Calcitic Limestone				35-40						
Dolomitic Limestone				20-25	15-25					
Various "fine" limes				20-40	0-20					

2.6.1 Sourcing NPK for Blending in Ghana

Ghana currently does not have deposits of the various elements for commercial production. Import of elements from the international market is the main source of raw materials (elements) for fertilizer blending in the country. Blending companies are advised to establish reliable sources of raw material supply to allow for sustainable and continuous production.

To avoid external shocks, it is good to look for sources of your raw material closer to your plant. As mentioned in the introduction, Annex G1 and Annex G3 list where nitrogen and phosphorus, organic fertilizers, soil supplements, and micro nutrients can be sourced. A blend operator must be aware of and adhere to any country-specific fertilizer raw material prohibition list regarding importation and use.



2.6.2 Guidelines on How to Source Raw Materials

It is important to source the right raw materials, with the right quality, at the right time, and for the right price. To achieve this, the following guidelines can be used:

1. Analyse the blend formula to determine the raw materials required and the quantities needed.
2. Understand the characteristics of each raw material required, e.g. the nutrient content, chemical compatibility, critical relative humidity, physical compatibility, and properties.
3. Ensure that the raw materials required are available in local or global markets.
4. Purchase the raw materials in a timely manner to ensure availability year-round, considering Ghana often has both rainy season farming (March/April to August/September) and dry season farming (October to February).
5. Request an internationally recognized safety data sheet (SDS) or Certificate of Analysis (CoA) for the materials being purchased so that vital information, such as the nutrient concentration, is available.
6. Conduct internal testing to confirm the information provided by the supplier. For example, material characteristics, such as nutrient content, particle size, product humidity, and product compatibility, should be verified. This means a well-equipped laboratory will be needed within the production facility.

2.6.3 Nutrient Concentration

Nutrient concentration is the proportion of nutrient (percentage) contained in every granule of a fertilizer raw material. To produce a quality blend, the nutrient concentrations of the raw materials required must be known. Poor-quality blends can be produced when a raw material that has a concentration of a nutrient below specifications is used. Raw material suppliers must provide analysis reports showing the nutrient concentrations and other characteristics of each material they sell.

However, the onus is on the buyer or the blender to carry out their own analysis to confirm the results before using raw materials in the production of a blend. Annex H shows a summary of required plant nutrients. However, the lab analysis of the raw material will be used to know the actual nutrient content of the raw material for eventual adjustment to the formula.

2.7 Receiving And Storing Raw Materials

Raw materials are expensive and constitute the largest expenditure in a fertilizer bulk blending operation. Handling them properly during transportation and storage is very important to preserve their nutrient content and physical properties, as provided for under regulations 19 to 21 of the Plants Fertilizer Regulation, 2012 (LI 2194) relating to registration and storage of fertilizer products. Refer to Annex I for indications of raw material receipt and storage layout.

2.7.1 Guidelines on how to receive and store raw materials

To receive and store raw materials adequately, the following serve as guidelines for an operation:

2.7.1.1 Chemical compatibility

Knowing the chemical compatibility of your fertilizer raw materials is central to quality blending outputs. The chemical compatibility of a fertilizer raw material is the measure of how stable it is when blended with another raw material. If two or more fertilizer ingredients can be blended and their characteristics remain stable individually and collectively, they are compatible.

When selecting raw materials for blending, the chemical compatibility of the materials should be the first characteristic to consider. A fertilizer raw material compatibility chart can be found in Annex J. Examples of some materials commonly used in Ghana with compatibility issues are urea, single superphosphate (SSP), triple superphosphate (TSP), and ammonium nitrate fertilizers. Moreover, sulphates and phosphates should not be blended with calcium-based fertilizers. Examples of partially compatible materials commonly used in the region are urea and MOP.

In hygroscopic products, moisture exchange occurs between the particles and the surrounding air. The moisture exchange is defined by the critical relative humidity (CRH) curve. The CRH curve is an equilibrium curve where the relative humidity of the surrounding air is plotted against the surrounding temperature.

Therefore, at a given temperature, if the relative humidity is above the curve, the particle soaks up moisture from the air. Or if the relative humidity of the atmosphere is below the curve, the air soaks up moisture from the particle. In effect, temperature is inversely proportional to relative humidity. Therefore, when air temperature increases, CRH decreases and vice versa.

Annex K shows the CRH of common fertilizers, raw materials and those commonly used in Ghana. Blended fertilizers usually have CRH values lower than that of each of the individual raw materials used to formulate the blend. To prevent a raw material from being affected by the relative humidity of the surrounding air when stored for a long period of time, it should be covered with plastic sheets or the surrounding air should be controlled in a manner that maintains the moisture content level. This is important so that the quality of the raw material is not compromised.

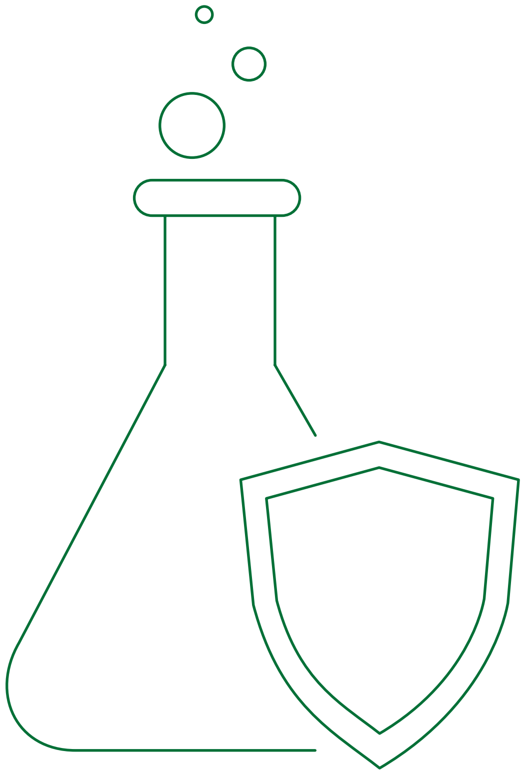
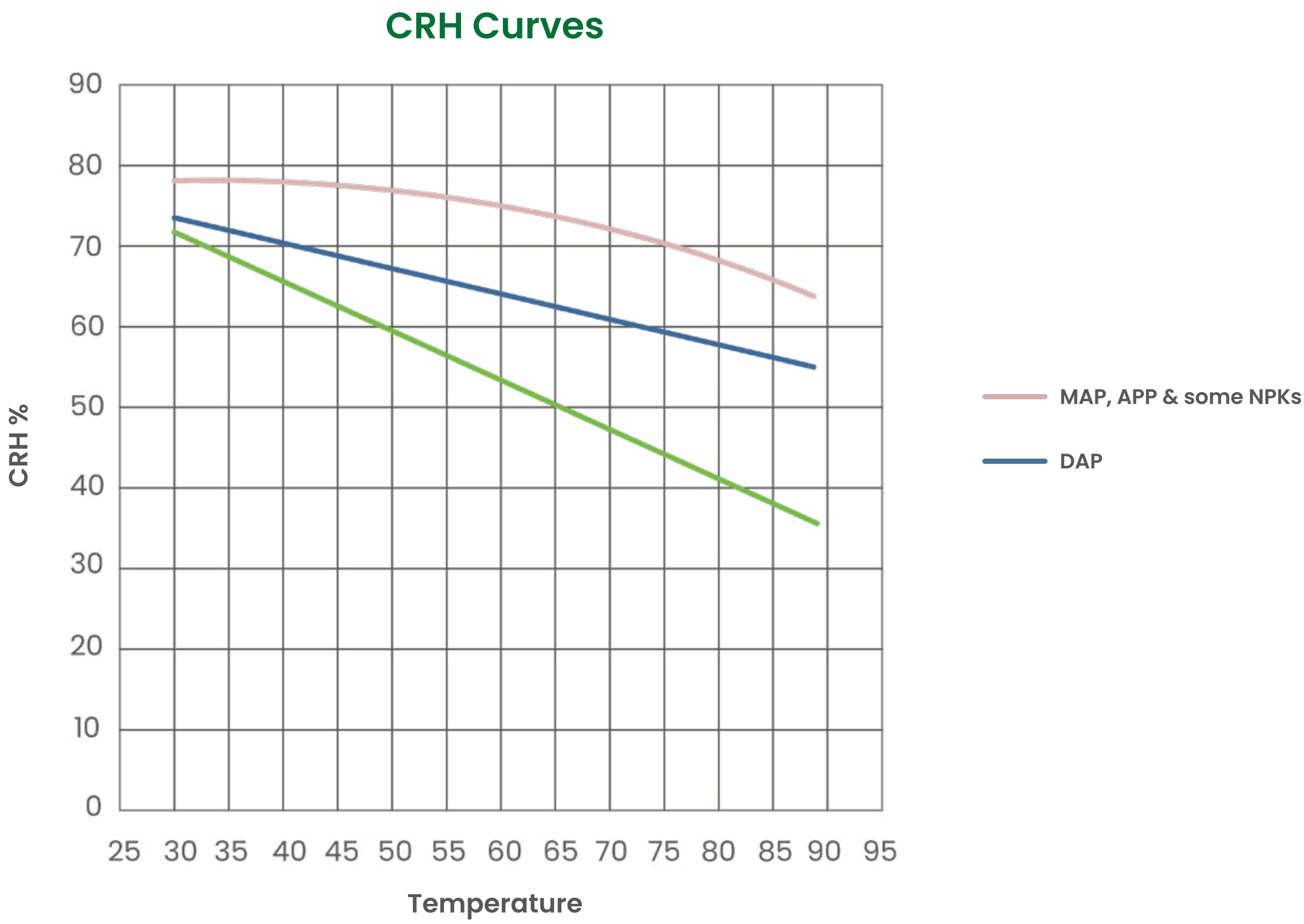


Figure 3 : CRH curves. T °C vs. CRH %



2.7.1.2 Physical compatibility

The physical compatibility of fertilizer's raw materials is essential in the production of quality blends. Physical characteristics of raw materials, such as bulk density, shape, hardness, solubility, dust content, flow rate, and level of contamination, can determine how physically compatible the raw materials are. For example, if the sizes of raw materials to be used in a blend differ by more than 10%, segregation will most likely occur during transportation. This is also true for micro nutrients because they usually have a high density and are required in small quantities.

2.7.1.3 Particle Size And Particle Size Distribution

When sourcing raw materials, the manufacturer should provide the particle size (using the size guide number, or SGN) and particle size distribution (using the uniformity index, or UI). Poor matching of particle sizes leads to product segregation and contributes to low-quality blends. Depending on the source of fertilizer raw materials, particles that are fine or lumpy in nature may be present in the bulk fertilizer. Sieving or screening raw materials before blending and bagging operations commence is good practice. However, sieving or screening should not be done after blending because the different raw materials will be separated and some particle loss may occur, thus changing the nutrient composition of the mixture. Blending plants should have lump and fine screeners in the blending and bagging lines.

There are two main methods of determining the particle size of fertilizer raw materials: the jar test and SGN/UI:

1. The Jar Test

This is a method used to determine the particle size distribution of raw materials. These results are important to determine if segregation will occur. Jars of equal sizes, straight sides and screens arranged together are required for the test.

Refer to Annex L for examples of jar test diagrams and particle size distributions. The test compares raw materials using their volume. An equal volume of each raw material to be used for blending is passed through screens. The materials retained on each screen and those that pass through the fines screen are placed into different jars and visually compared. Materials of similar size distributions will not segregate when used for blends. Screens between Tyler sizes 5 and 20 will work, but for more uniform results, only two screen sizes, i.e. mesh sizes 7 and 9 or 8 and 10, should be used.

2. Size Guide Number/Uniformity Index Method

The SGN/UI is another system used to identify the particle size distribution of raw materials. The SGN is the particle size that divides the mass of all the particles of the raw materials into equal halves, i.e. one with the larger particle size and the other with the smaller particle size. In other words, it is the median dimension in millimetres to a second decimal place multiplied by 100. The SGN can be determined using any of the following methods, a graph (see Annex M), calculation from size analysis data (see Annex N), or estimation using the SGN scale (see Annex O).

The UI is best determined by a mathematical calculation. It is the ratio of small particle sizes to large particle sizes, expressed as a percentage. In other words, it is the ratio of particle sizes matching the 95% level and those matching the 10% level in the cumulative distribution curve multiplied by 100.

RAW MATERIAL	SGN	UI
A	250	50
B	210	45
C	260	55
Average	240	50
Acceptable Range	215-265	45-55

Table 4. Some important physical properties of fertilizer raw materials

EFBA TARGETS AND TOLERANCES FOR THE GRANULATION OF RAW MATERIALS FOR FERTILIZER BLENDING			
NOTATION	**PHYSICAL DIMENSION**		
Mean Particle Size	d50 in mm	3.25 mm	+/- 0.25 mm
Fine Particles	< 1 mm, % of mass	0%	0.25%
Coarse Particles	> 5 mm, % of mass	0%	1%
Main Range	2.5–4.0 mm, % of mass	90%	+/- 5%
Granulometric Spread Index (GSI)	$GSI = \frac{d_{84} - d_{16}}{2\ d_{50}}\ 100$	< 18	-

2.7.1.4 Storage Procedures

- Refer to in-house SOPs for receiving and warehouse storage procedures. However, note the four critical points below:
    - Holding bays/bins for each raw material should be pre-planned, taking into account the chemical compatibility of the different raw materials. Use the compatibility chart in Annex J to ensure their safe storage.
    - A transport medium in good condition should be used to convey the cargo.
    - The products being carried in trucks should be covered and secured with a tarpaulin, so that the product does not get wet (in case of rain), become contaminated, or spill onto the road surface, into public drains, or waterways.
    - The bays/bins should be adequately sized to contain the incoming product. The space should not be overfilled so that products do not spill into other bays/bins and cause contamination.
- Samples must be taken carefully, labelled appropriately, and sent to a laboratory for analysis and/or kept on-site for reference purposes. Refer to sampling and testing methods in Annex P.
- Contact the supplier immediately if the raw material received does not meet the nutrient concentration and particle size requirements
- Use the jar test and SGN/UI methods for quick sampling and physical testing
- For more in-depth testing, a riffled portion should be used for chemical analysis.
- For raw materials received in bags, carefully arrange them in a pile and store them in a manner that allows easy and safe access. For safety reasons:
    - Stockpile height for raw materials in bulk should be at least 6 metres.
    - Where applicable, use an overhead conveyor system or a trapezoid-shaped flow diverter with a hole in the middle.

- In the absence of an overhead conveyor system, carefully decant bags of raw materials into product bays and ensure bags are emptied from a height and dropped at different streaming points.
- While feeding hoppers for production, the front-end loader should not pick up product from only one end of a stockpile but should work the pile from one end of the bay/bin to the other.
- If a vertical face is created in a stockpile, it should be knocked down gently for safety and to ensure product uniformity

2.8 Calculate Blend Composition

When blend specifications are received, operators calculate how much of each raw material is required to satisfy the recommendation. Though the calculation can be done manually, the use of fertilizer blend calculation software is encouraged to avoid human error. There are many types of blend calculation software. The manufacturer or an experienced agronomist can suggest appropriate options. This manual will discuss the steps to take when manually calculating ingredients in a blended formula.

2.8.1 Manual Calculations

Before commencing manual calculation, it is important to select the correct fertilizer raw materials (Section 2.6), understand the physical and chemical compatibility of the raw materials, and ensure the values of the nutrient content of the raw materials in stock are guaranteed.

Example 1: A Simple NPK Blend

The following steps can serve as a guide to performing accurate calculations. NPK 20-10-10 will be used as the initial example.

1. Choose the blending ingredients:

a) The most common sources of N are urea, ammonium sulphate, and ammonium from DAP and MAP. Some NPS compounds, such as 19-38-0+7S, are also appropriate for blending.

b) The most common P sources are DAP and MAP; other appropriate P sources may include 19-38-0+7S or similar products. TSP may be used for certain blends but is not compatible with most N sources.

c) The most common K source is KCl (or MOP). SOP is a very good K source but is expensive relative to MOP.

d) Other common blend ingredients and their nutrient compositions are shown in Table 3. For this example, DAP and KCl have been chosen as the blending ingredients.

2. Check for ingredients compatibility. Note that CRH data is not available for three-ingredient blends, and added ingredients tend to decrease CRH. It is prudent to determine the CRH of a particular blend beforehand, particularly before producing it in large quantities.
3. Calculate the nutrients in the blend on a per metric ton (1,000 kg) basis. The concentrations of nutrients in an NPK formulation are expressed as percentages; for example, NPK 20-10-10 has 20% N, 10% P_2O_5, and 10% K_2O. To convert these percentages to kilograms per metric ton, multiply by 10. A metric ton of NPK 20-10-10 will therefore contain 200 kg N, 100 kg P_2O_5, and 100 kg K_2O.
4. The P source in NPK blends will contain both N and P. Always begin by calculating the P required first. To calculate the kilograms of DAP to supply 100 kg of P_2O_5 (from step 3), divide the kilograms of required P_2O_5 by the percentage of P_2O_5 in DAP, which is typically 46%.

Note that percent is kilograms per 100 kg, so:

$$\frac{100\ kg\ P_2 0_5}{mt\ fertilizer} \times \frac{100\ kg\ DAP}{46\ kg\ P_2 0_5} = \frac{217.4\ kg\ DAP}{mt\ fertilizer}$$

Since DAP also contains N, the quantity of N in this DAP is calculated as the kilograms of DAP times the percentage N in DAP:

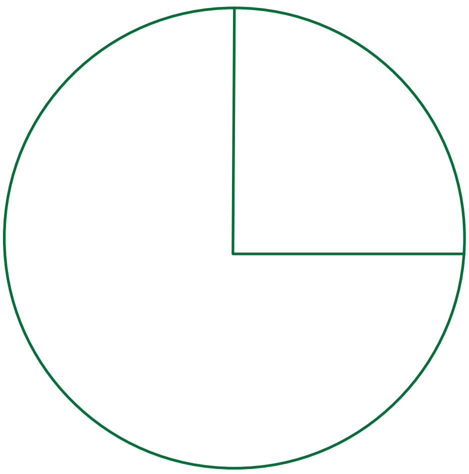
$$\frac{42.9\ kg\ ZnSO_4 * H_2 0}{mt\ fertilizer} \times \frac{17\ kg\ S}{100\ kg\ ZnSO_4 * H_2 0} = \frac{7.3\ kg\ S}{mt\ fertilizer}$$

The total N requirement is 200 kg N/mt, of which DAP is supplying 39.1 kg. The balance, or 200 – 39.1 = 160.9 kg N/mt, must be supplied by the chosen N source urea. The quantity of urea required per metric ton is calculated by dividing this by the percentage N in urea:

$$\frac{160.9\ kg\ N}{mt\ fertilizer} \times \frac{100\ kg\ urea}{46\ kg\ N} = \frac{349.8\ kg\ urea}{mt\ fertilizer}$$

5. Finally, MOP is supplying 100 kg of K_2O per metric ton, which is calculated by dividing the required quantity of K_2O by the percentage K_2O in KCl, 60%:

$$\frac{160.9\ kg\ N}{mt\ fertilizer} \times \frac{100\ kg\ urea}{46\ kg\ N} = \frac{349.8\ kg\ urea}{mt\ fertilizer}$$



The total amount of ingredients in the metric ton of 20-10-10 is therefore 349.8 kg urea, 217.4 kg of DAP, and 166.7 kg KCl, for a total of 733.9 kg. The balance of the 1,000 kg or metric ton is 1,000 – 733.9 kg, which is 266.1 kg.

Below is a calculation sheet showing the nutrients supplied from each source, rounded to the nearest kg:

RAW MATERIAL	WEIGHT	N	P_2O_5	K_2O
	- - - - - - - kg/mt - - - - - - -			
MOP (0-0-60)	167	0	0	100
DAP (18-46-0)	217	39	100	0
Urea (46-0-0)	350	161	0	0
Filler (0-0-0)	266	0	0	0
Total	1,000	200	100	100
Percentage		20	10	10

Note that there is limited compatibility between MOP and urea, a combination likely to cake due to low CRH. Anti-caking agents should be considered in this case.

Example 2: A Multi-nutrient Fertilizer Blend

Next, the calculation will be done for a more complicated blend that has a balance of macro- and micro nutrients: 20-10-10+5S+1.5Zn+1B.

The addition of S to the formula creates some choices for the blender, as it can be supplied from several sources, including ammonium sulphate, sulphur pastilles, potassium sulphate, polyhalite, or 19-38-0+7S, or some combination of the above. Key considerations will be cost, product stability, and ingredient availability.

For this example, ammonium sulphate, which is usually inexpensive, will be used. The Zn source will be zinc sulphate monohydrate, usually the least expensive and most stable Zn source.

The Zn requirement will be calculated first since it makes a small S contribution, the balance of which will be made with the ammonium sulphate. The B will come from granular borax pentahydrate (14.5% B), a stable granular B source.

1. Multiplying the percentages in the formulation by 10, a metric ton of the formulation will contain 200 kg N, 100 kg P_2O_5, 100 kg K_2O, 50 kg S, 15 kg Zn, and 10 kg of B.

2. Calculate the ingredients required, beginning with Zn:

$$\frac{15\ kg\ Zn}{mt\ fertilizer} \times \frac{100\ kg\ ZnSO_4 * H_2O}{35\ kg\ Zn} = \frac{42.9\ kg\ ZnSO_4 * H_2O}{mt\ fertilizer}$$

3. Now, calculate the amount of S in this quantity of ZnSO4*H_2O:

$$\frac{42.9\ kg\ ZnSO_4 * H_2O}{mt\ fertilizer} \times \frac{17\ kg\ S}{100\ kg\ ZnSO_4 * H_2O} = \frac{7.3\ kg\ S}{mt\ fertilizer}$$

The total S required is 50 kg/mt, so the balance of S that must be supplied by the ammonium sulfate (AS) is 50 – 7.3 = 42.7 kg S/mt.

4. Now calculate the ammonium sulfate required:

$$\frac{42.7\ kg\ s}{mt\ fertilizer} \times \frac{100\ kg\ AS}{24\ kg\ S} = \frac{178.0\ kg\ AS}{mt\ fertilizer}$$

5. The AS also contains N, calculated as follows:

$$\frac{178.0\ kg\ AS}{mt\ fertilizer} \times \frac{21\ kg\ N}{100\ kg\ AS} = \frac{37.3\ kg\ N}{mt\ fertilizer}$$

6. The P_2O_5 from DAP, the N from DAP, and the K2O from MOP are calculated as shown previously:

$$\frac{100\ kg\ P_2O_5}{mt\ fertilizer} \times \frac{100\ kg\ DAP}{46\ kg\ P_2O_5} = \frac{217.4\ kg\ DAP}{mt\ fertilizer}$$

$$\frac{217.4\ kg\ DAP}{mt\ fertilizer} \times \frac{18\ kg\ N}{100\ kg\ DAP} = \frac{39.1\ kg\ N}{mt\ fertilizer}$$

$$\frac{100\ kg\ K_2O}{mt\ fertilizer} \times \frac{100\ kg\ MOP}{60\ kg\ K_2O} = \frac{166.7\ kg\ MOP}{mt\ fertilizer}$$

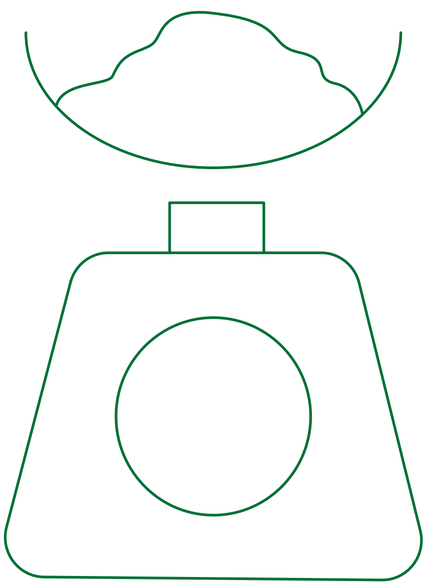
7. The N balance is the total N required (200 kg/mt), minus the N supplied in the DAP and AS, or 7. 200 – 37.3 – 39.1 = 123.6 kg N/mt, and the amount of urea required for that balance is:

$$\frac{123.6\ kg\ N}{mt\ fertilizer} \times \frac{100\ kg\ urea}{46\ kg\ N} = \frac{268.7\ kg\ urea}{mt\ fertilizer}$$

8. Finally, the amount of borax pentahydrate (14.5% B) is calculated:

$$\frac{10\ kg\ B}{mt\ fertilizer} \times \frac{100\ kg\ borax\ penta.}{14.5\ kg\ B} = \frac{69.0\ kg\ borax\ penta.}{mt\ fertilizer}$$

The total amount of ingredients per metric ton is (268.7 kg urea + 217.4 kg DAP + 166.7 kg MOP + 178.8 kg AS + 42.9 kg Zn sulfate monohydrate + 69.0 kg borax pentahydrate)/mt = 943.5 kg. A balance of 56.5 kg of filler is required to bring the total weight to 1 mt.



Below is the calculation sheet showing the nutrients supplied from each source, rounded to the nearest kg:

RAW MATERIAL	WEIGHT	N	P_2O_5	K_2O	S	Zn	B
	- - - - - - - - - - - - - - - - -	kg/mt	- - - - - - - - - - - - - - - - -				
Urea (46-0-0)	269	124	0	0	0	0	0
AS (21-0-0+24S)	179	37	0	0	42.7	0	0
DAP (18-46-0)	217	39	100	0	0	0	0
MOP (0-0-60)	167	0	0	100	0	0	0
ZnSO4*H_2O (35 Zn, 17 S)	43	0	0	0	7.3	15	
Borax penta. (14.5 B)	69	0	0	0	0	0	10
Filler (0-0-0)	44	0	0	0	0	0	10
Total	1,000	200	100	100	50	15	10
Percentage		20	10	10	5	1.5	1

Example 3: Over-Formulation Of A Multi-Nutrient Fertilizer Blend

Assume another blend which has a balance of macro- and micronutrients: 14-18-18+5S+1B+2.5CaO.

For this example, ammonium sulfate will be used. The calcium source will be calcitic limestone (40% Ca) since it is available in Ghana.
So, multiply 2.5CaO by 0.7147 to get 1.79Ca. The Ca requirement will be calculated first and the B will come from boric acid (17.5% B). So, divide 1B by 3.218 to get 0.311 B_2O_3.

1. Multiplying the percentages in the formulation by 10, a metric ton of formulation will contain 140 kg N, 180 kg P_2O_5, 180 kg K_2O, 50 kg S, 3.11 kg B, and 18 kg Ca.

2. Calculate the ingredients required, beginning with Ca:

$$\frac{18\ kg\ Ca}{mt\ fertilizer} \times \frac{100\ kg\ CaCO_3}{40\ kg\ Ca} = \frac{45\ kg\ CaCO_3}{mt\ fertilizer}$$

3. Calculate the ammonium sulfate required:

$$\frac{50\ kg\ S}{mt\ fertilizer} \times \frac{100\ kg\ AS}{24\ kg\ S} = \frac{208\ kg\ AS}{mt\ fertilizer}$$

4. The AS also contains N, calculated as follows:

$$\frac{208\ kg\ AS}{mt\ fertilizer} \times \frac{21\ kg\ N}{100\ kg\ AS} = \frac{44\ kg\ N}{mt\ fertilizer}$$

5. The P_2O_5 from DAP, the N from DAP, and the K_2O from MOP are calculated as shown previously:

$$\frac{180\ kg\ P_2O_5}{mt\ fertilizer} \times \frac{100\ kg\ DAP}{46\ kg\ P_2O_5} = \frac{391\ kg\ DAP}{mt\ fertilizer}$$

$$\frac{391\ kg\ DAP}{mt\ fertilizer} \times \frac{18\ kg\ N}{100\ kg\ DAP} = \frac{70\ kg\ N}{mt\ fertilizer}$$

$$\frac{180\ kg\ K_2O}{mt\ fertilizer} \times \frac{100\ kg\ MOP}{60\ kg\ K_2O} = \frac{300\ kg\ MOP}{mt\ fertilizer}$$

6. The N balance is the total N required (140 kg/mt), minus the N supplied in the DAP and AS, or 6. 140 – 44 – 70 = 26 kg N/mt. The amount of urea required for that balance is:

$$\frac{26\ kg\ N}{mt\ fertilizer} \times \frac{100\ kg\ urea}{46\ kg\ N} = \frac{57\ kg\ urea}{mt\ fertilizer}$$

7. Finally, the amount of boric acid (17.5% B) is calculated:

$$\frac{3.11\ kg\ B}{mt\ fertilizer} \times \frac{100\ kg\ boric\ acid.}{17.5\ kg\ B} = \frac{18\ \ kg\ boric\ acid.}{mt\ fertilizer}$$

The total amount of ingredients per metric ton is (57 kg urea + 391 kg DAP + 300 kg MOP + 208 kg AS + 45 kg Ca + 18 kg boric acid)/mt = 1,019 kg.

What happened above is a case of overformulation. Overformulation occurs when the total kilograms of raw materials exceeds the 1,000 kg in a metric ton.

To make the blend work, adjust the concentration of N, P_2O_5, and K_2O to accommodate the desired target for S, B, and Ca. Alternatively, S, B, and Ca can be adjusted if the NPK of the blend must remain the same. Otherwise, all or some of the nutrients can be adjusted so the total ratio of nutrients will remain the same.

In this example, most of the nutrients will be adjusted.

Below is the calculation sheet showing the pre-and post-adjustment amount of nutrients supplied from each source, rounded to the nearest kg:

RAW MATERIAL	N	P_2O_5	K_2O	S	Zn	B	WEIGHT	1.9% ADJUSTMENT	WEIGHT 2
	- kg/mt -								
Urea (46-0-0)	26	0	0	0	0	0	57	1	56
AS (21-0-0+24S)	44	0	0	50	0	0	208	4	204
DAP (18-46-0)	70	180	0	0	0	0	391	7	384
MOP (0-0-60)	0	0	180	0	0	0	300	6	294
$ZnSO4*H_2O$ (35 Zn, 17 S)	0	0	0	0	18		45	1	44
Borax penta. (14.5 B)	0	0	0	0	0	3.11	18	0	18
Filler (0-0-0)	0	0	0	0	0	0	0	0	0
Total	140	180	180	50	18	3.11	1019	19	100
Percentage	14	18	18	5	1.8	0.311	57		

NOTES:

- The adjustment factor of 1.9% is derived from the ratio between the 19kg excess weight over the 1,000 kg expected weight multiplied by 100%
- 2.5CaO becomes 1.8Ca because the source of Ca is calcitic limestone, which has a nutrient content in Ca.
- 1B becomes 0.311B because the source of B is boric acid, which has a nutrient content in B and is not boron in its pure elemental form.
- The blend formula that should be printed on the package is 14-18-18+5S+0.311B+1.8CaO.

2.9. Bulk Blending And Bagging

To produce a quality blend, the next step is to carry out the blending and bagging operations to acceptable Ghanaian and international standards. Fertilizer blending and bagging is the process of mixing fertilizers raw materials that flow freely, adding any liquid coatings, and packaging them into bags with open mouths. Adding micro nutrients to an NPK blend is necessary to attain balanced nutrition for agricultural soils and plants, yet this poses a challenge to the blenders due to the small quantities required. So, an operator should take the nature of the micro nutrient (liquid, powder, granular) being used into consideration and purchase a plant with a good micro nutrient impregnation system.

2.9.1 Production Operations

Every blender should have an internally developed set of SOPs in addition to those listed in the plant's manual. These SOPs work to guide the entire process by ensuring operational uniformity. For further reference, Annex Q contains an indicative checklist for bulk blending and bagging operations. The following serves as general guidance.

1. Use a good quality batch or continuous blending system to produce accurate blends. Attention must be paid to the type of plant used for blending. If an ordinary mixer is used in place of a blending system, there is a very high probability that inaccurate blend products will be produced. This is one way of getting low-quality blends with misrepresented bag weights into the market.

2. For a batch or continuous system, the general functions include, but are not limited to:

   a) Set the plant and scales to your predetermined zero setting.

   b) Load raw materials in receiving hopper(s).

   c) Start the blending process.

   d) Start the bagging process simultaneously with the blending process.

   e) Start the bag stitching process simultaneously with the bagging process.

   f) Palletize and store as required.

   g) See Section 5.2 (1g) for recommended bag characteristics and Section 3.1.1 for blended product storage guidelines.

3. The following are some scenarios for each type of bulk blending plant that can affect the quality of blends.

   Batch Type

   - Low-quality raw materials, e.g.,. lumpy, moist, low nutrient content value, etc., are used because the mixer/blender is a drum type, which can handle this.
   - The entire line is not properly cleaned in between batches, especially if different blend specifications.
   - The weights and quantities of raw materials are inaccurately calculated or fed into the hopper(s) in the wrong manner.

   Continuous Type

   - The raw materials do not flow freely.
   - The raw materials are not fed into the hoppers at a constant rate (speed).
   - A hopper is fed with material that it was not calibrated for.
   - The wrong blend formula is programmed.

- There is an obstruction in any section of the plant causing inaccurate weight readings at either the feed hoppers or bagging pre-weighers, e.g.,. if an operator physically stands in any of the hoppers, the weighing system will calculate the wrong weight, which will affect the final bag weight.

2.9.2 Packaging

The packaging of blends must meet the following requirements:

1. All fertilizer bags should be labelled as provided for under:
    - Article 5 Chapter II and Article 18 Chapter IV of ECOWAS Regulation C/REG.13/12/12, relating to the principle of truth-in-labelling and labelling.
    - Articles 3-6 Chapter II of ECOWAS Implementing Regulation ECW/PEC/IR/02/03/16, relating to labelling requirements.
2. Labelling should be permanent, written in English, clear, and prominent.
3. As stipulated by the regulation, labelling must be in English.
4. The dates of manufacture and expiration of the product must be indicated.
5. PFRD Number must be displayed.
6. Each bag should be properly stitched, so the product in the bag is tightly secured. This will help prevent product segregation while in storage or transit.
7. Depending on the product, choose the appropriate size of the bag. (Urea bigger bags than phosphate)
    - For products that are more hygroscopic or if you are planning to keep the product for long, you will need a thicker bag.

The following specifications for fertilizer bag labels are recommended (Figure 4)

- Name and address of blender or manufacturer
- PFRD number
- Fertilizer grade
- Guaranteed nutrients
- Sources of nutrients
- Net weight
- Batch number
- Date of blending
- Net weight

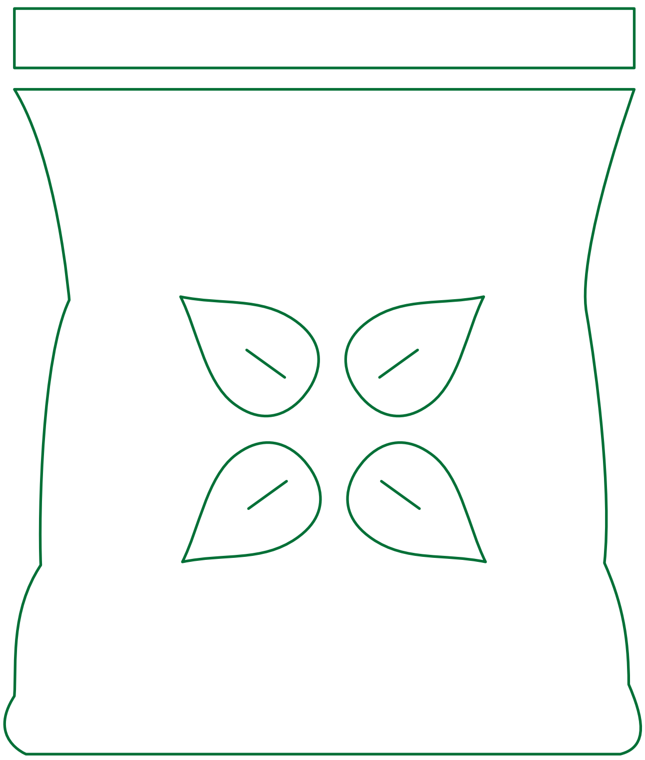


Figure 4. ECOWAS fertilizer bag labeling regulation.

Additional labeling required in Ghana is indicated in yellow

ECOWAS
FERTILIZER LABELING

ECONOMIC COMMUNITY OF WEST AFRICAN STATES

(Ref. Implementing Regulation ECW/PEC/IR/02/03/16)

Source: ECOWAS Implementing Regulation ECW/PEC/IR/02/03/16

The label illustrated here is not a standard. It's a model that simply shows the minimum information required on fertilizer labels, as prescribed by an ECOWAS Implementing Regulation on labelling.

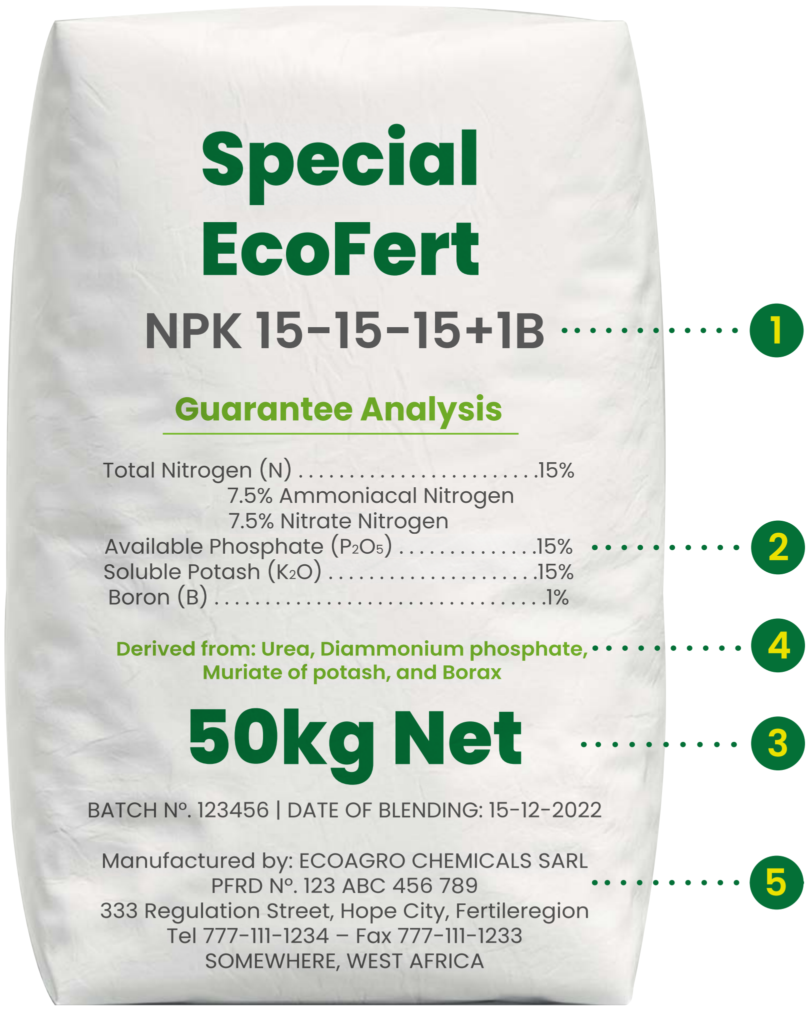
THE BIG FIVE

Five required components must appear on a fertilizer label:

1. Grade
2. Guaranteed analysis
3. Net weight
4. Sources of nutrients
5. Name and address of the manufacturer, importer or re-packing agent

GRADE

Grade is a shorthand representation of the guarantees for Total Nitrogen (N), Available Phosphate (P_2O_5) and Soluble Potash (K_2O) with each guarantee separated by a hyphen, "-", e.g., 15-15-15. The grade shall be in whole numbers and in the same terms, order, and percentages as in the guaranteed analysis.



2.9.3 Plant Maintenance

Plant maintenance refers to the actions taken to maintain an existing plant or return it to its optimal operating level. For any production operation, it is important to note the five types of maintenance. These are reactive, preventive, predictive, routine, and planned maintenance. Except for reactive maintenance, these types of maintenance are proactive in nature.

Guidelines for Plant Maintenance

- Only skilled staff should operate and maintain the plant. A good practice is to have staff trained by the plant manufacturer and involved during the installation and commissioning of the plant.
- The plant should be kept clean and devoid of obstacles that could hinder its operation. Note that this is simple preventive maintenance and is not related to plant malfunction or failure.
- All products stuck within crevices and along the blending or bagging line pathway should be removed in a manner that will not affect the structure of the plant
- An air compressor can be used for dry products and a rag for wet or caked products.
- A good cleaning agent should be recirculated through the pumping system of liquid impregnators to clean it out.
- The fastenings and mountings of all moving parts and parts prone to vibration should be checked. Any looseness, restricted motion, or deviation should be noted and reported.

Every plant supplier should supply a maintenance manual along with the plant. An adequate maintenance schedule will have a detailed tool and consumables list. The supplier must advise as to which tools and consumables are essential with regard to the type and size of plant being supplied. To effectively maintain a plant, refer to Annex R for an indicative maintenance checklist that can be used on every part of the plant.

2.9.4 Plant And General Safety

For general safety within and around the facility, the internally developed set of safety SOPs must be adhered to for the safety of personnel, raw materials, equipment, and finished products. Toolbox Talks should be given every shift. The safety-first principle should be practised in carrying out every activity.

Standard safety signs should be placed at designated points and must be visible to all. Examples of standard safety signs can be found at https://www.safetysignonline.co.za/. If safety classification systems are understood and adhered to, identifying risks will be easier. Refer to Annex S for an indicative plant safety checklist for steps detailing how the movement of staff and mobile equipment should be conducted around the plant.

Guidelines for Plant And General Safety

The following are guidelines for good safety management practices in production and storage. For the guidelines to be successfully implemented, total support and commitment should be given by the line management of the operations.

- Practice housekeeping of a high standard in every operation.
- Develop annual safety targets, with action plans for what, who, and when. Form a safety committee made up of the operations manager and members from each section of the company. Attendance at safety meetings should be mandatory for all.
- Evaluate all activities with consideration for safety. Carry out an activity safety analysis for the activities classified as critical.

Describe critical activities in the procedures and highlight those that require special personal protective equipment and gear. Train personnel accordingly. ¡ Create a preventive maintenance system and ensure its implementation by supervisors.

- Establish a work permit system for all special work including a 'LOG OUT TAG OUT' (LOTTO) system.
- Establish a work approval system for all contractors. ¡ Thoroughly review and receive approval before modifying any process
- Report and investigate all hazards, near misses, and accidents and apply corrective actions where applicable.
- Establish an emergency plan. Test this plan twice every year at a minimum. Develop the plan in conjunction with external emergency services.

2.9.5 Housekeeping

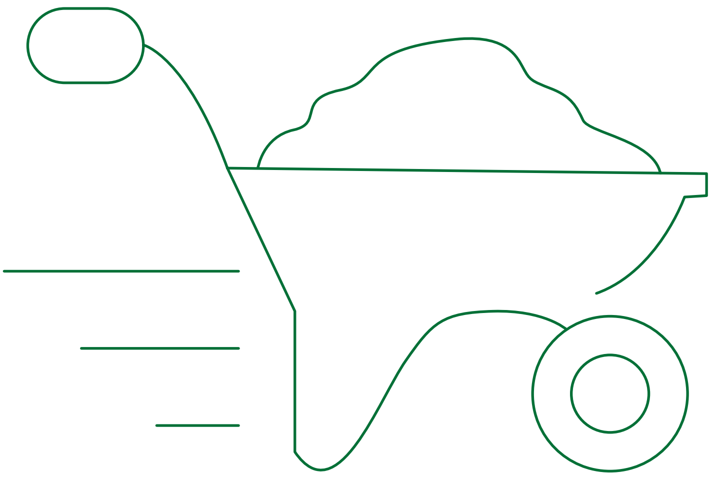
Good housekeeping at the facility is important because it can affect product quality, minimise product loss, and ensure the safety of operators.

Guidelines for Good Housekeeping Practices

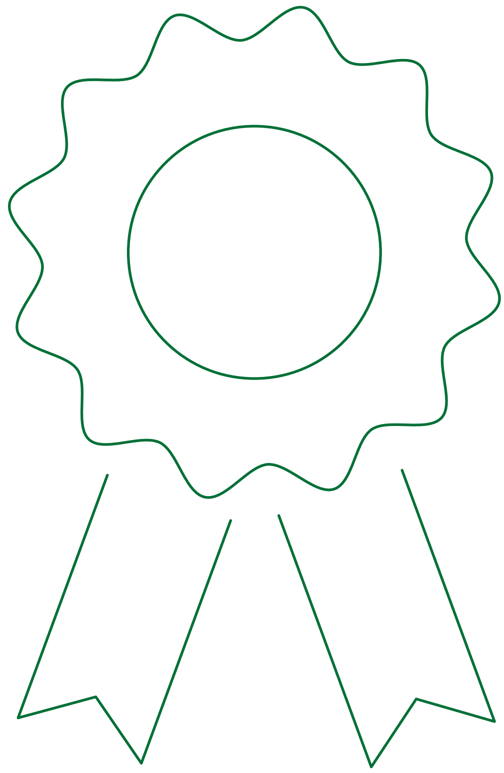
Every blender should have an internally developed set of SOPs for housekeeping. However, the following can serve as guidance to achieve standard housekeeping levels in a fertilizer bulk blending operation.

- Floor supervisors are to hold "Toolbox Talks" before and during every shift, highlighting the SOPs for housekeeping.
- Supervisors have a fundamental duty to provide concise information, training, personal protective equipment, and clear instructions as required to ensure the health and safety of all employees on the job.
- Continuous cleaning should be safely done during production and in between every fill. Spills should be swept up after every operation.
- Clean and uncontaminated spills should be mixed back with the main bulk product in its bay/bin.
- Dirty contaminated sweepings should be bagged and stored separately from the clean products.
- The plant should be cleaned after every shift
- For facilities with overhead conveyor belts, product spillage while the belt is running should be checked to prevent contamination of bulk products stored in the bays/bins below the belt.
- All workers should be on high alert in preventing contamination during receiving, storage, blending, and bagging operations because this is the main cause of bad or low-quality blends.

- All product bays/bins should be sealed properly at the bottom to prevent leakage and unplanned product mixture. The product bays/bins should be tall enough to prevent leakage and unplanned product mixes from the top when they are filled.
- Product hoppers should be arranged and aligned such that leakage through shutoff gates and from the top, when filled, is prevented.
- Loading operators must take care when transferring product from bays/bins to the hoppers to avoid drip spillage along the way.
- All driveways, accessways, and walkways within the confines of the warehouse should be kept free of fertilizer, debris, foreign materials/objects, and moisture.
- All product bays/bins, as well as product hoppers, should be labelled correctly.
- Some fertilizer raw materials are dusty in nature. Since dust is known to absorb moisture from the environment more quickly than granular materials, the plant and warehouse should be kept dust-free, as much as possible for as long as possible. This will help decelerate corrosion, reduce or eliminate slippery conditions, and improve the general appearance of the plant and warehouse.
- Do not always rely on others to clean things up. Put tools away tidily rather than leaving them laying around benches, on the floor, on scaffolding, resting on pipes, or in other positions. They can create trip hazards, fall onto a person, or get damaged in a fall. There is a place for everything, and everything should be in its place.
- When dismantling anything, stack the parts neatly and tidily. Do not leave materials in gangways because this could block an escape route or cause a hazard. When dismantling wood, make sure all nails are removed. If this is not possible, hammer nails flat and ensure that no part that could cause injury to anyone is left protruding. Damaged lengths or parts of wood should be cleared, as those also create hazards.
- All waste should be placed in dust bins or skips to be removed. Thus, if a fire occurs, it can be confined to a small area and dealt with quickly and efficiently, preventing it from spreading, especially in high winds.
- When finishing each shift, tools and equipment should be returned to storage. If tools are damaged, they should be repaired or replaced. They should not be left lying around as they can cause a hazard.
- Anyone who notices waste piling up and is not able to remove it should bring this to the attention of the supervisor.
- Anyone who is working at height and notices a loose object on a board or walkway should put this somewhere where it cannot be dislodged to prevent the item from falling and injuring someone.



2.10. Quality Control



Maintaining a high level of quality control in every aspect of the blending and bagging process will lead to the production of quality blends. Every blender should have an internally developed set of SOPs for quality control.

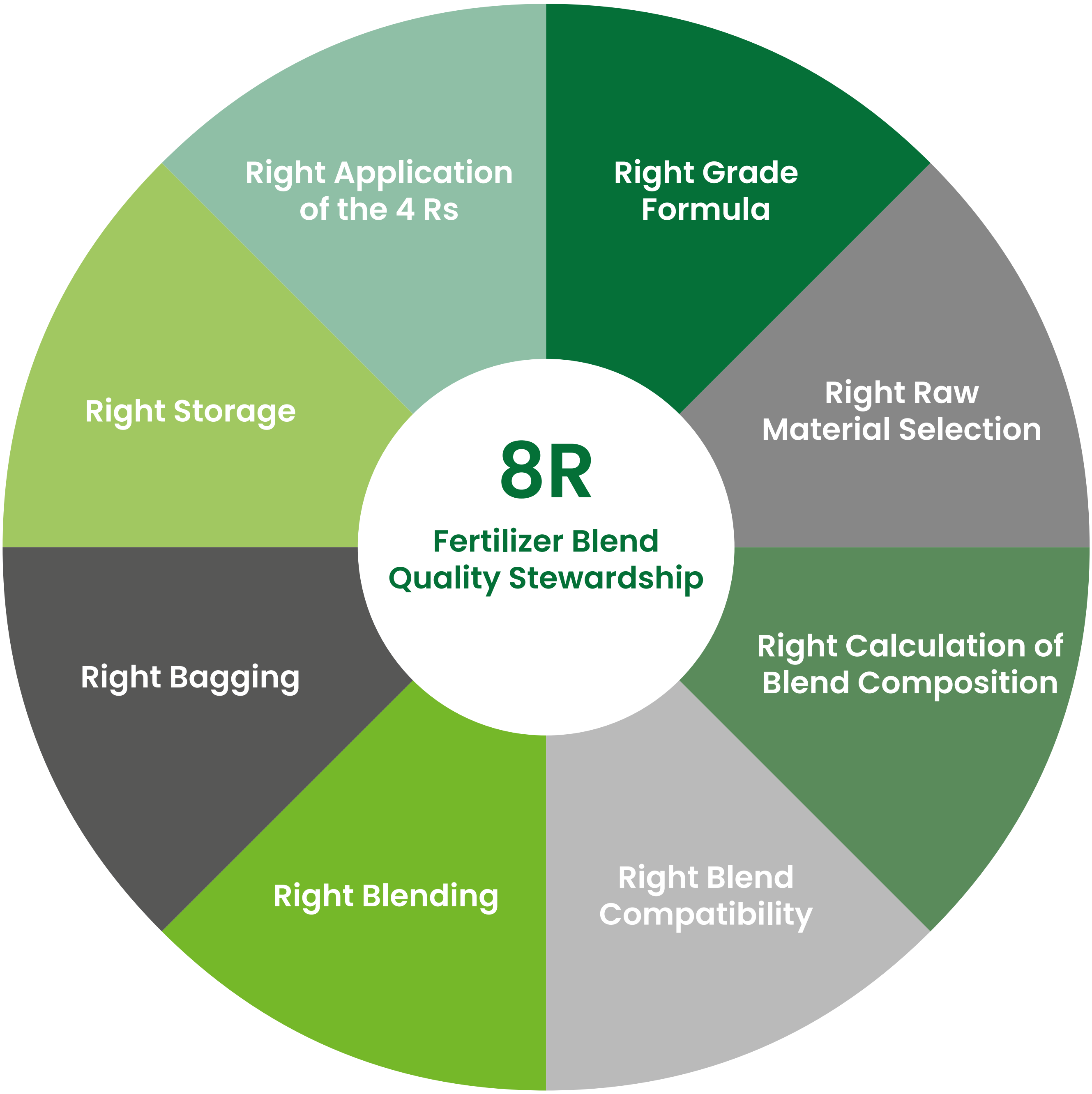
2.10.1 Quality Control for Finished Products

For finished products, blenders should comply with L.I. 2194 and Act 803. In addition, the blender should also have an internally developed set of SOPs for quality control of finished products that will help them comply with the above-mentioned Act and regulation.

Table 5. Quality parameters and their control measures

QUALITY PARAMETER	CONTROL MEASURE
Bag Weight	•Weigh randomly selected bags out of bagging line
Heavy Metal Content	•Verify parameter from Safety Data Sheet (SDS) •Test raw material on arrival
Nutrient Content	•Verify SDS •Review Certificate of Analysis for declared Content •Test Raw material on arrival •Test Finished Product •Do variance analysis
Presence of Foreign Material	•Physically examine raw materials and finished products to ensure no foreign materials are present
Other Harmful Substances	•Test finished products for potentially harmful ¡ ¡ingredients which can be injurious to certain plant growth at certain concentrations (chlorine), and appropriately issue note of caution on label

Figure 5. Product stewardship variables that impact blend quality



Source: 8R Fertilizer Blend Quality Stewardship™

Guidelines for Quality Control of Finished Products

Sampling

For accurate sampling, blenders must know the following:

- Acceptable sampling and testing methods (Annex P).
- The most appropriate sampling and testing equipment and methods (Annex P).
- Sample quantity to be collected.
- Increments in which samples should be taken.
- Length of time samples should be kept.
- What to do with the samples after the storage period elapses.

Sampling of materials is a serious undertaking and should not be taken lightly. It involves special procedures and requires dedicated equipment. Blenders must utilise recognized sampling methods, such as those described in this manual (see Annex P).

Collecting and analysing samples that do not represent the batch is pointless; hence, all samples must be correctly taken to ensure an accurate representation. Samples from every batch should be taken, analysed, and kept in compliance with L.I 2194. All samples should be stored at a temperature that correlates with the temperature where it would be applied. Blend samples can be stored for up to three years, and straight/raw material samples can be stored for up to two years.

Used samples must not be dumped into the general waste stream to prevent contamination of the environment. When the storage time expires, a sample can be put back into a new blending process of a blend or straight that matches its formulation.

Tolerance

Tolerance is defined as the permitted deviation of measured values of a nutrient content or bag weight below values claimed on the label or the maximum allowable heavy metal limits in a fertilizer, L.I. 2194 disposition stipulates the allowable heavy metal content (Regulation 33) and establishes the level of a nutrient in fertilizer (regulation 31) and section 91 of Act 803 short weight.

Regulation 27(1)(b)

Established levels of nutrients in fertilizers Investigational allowances and actual values

1. A fertilizer is deficient if the analysis of an official sample for any plant nutrient is below the guarantee by an amount exceeding the values stated in **Table 6.**
2. A fertilizer is deficient if the actual value is less than ninety-eight percent of the guaranteed value. The actual value is calculated by comparing the value guaranteed with the value found. Plant nutrient values will be calculated on the basis of the price documented in the inspection report for the inspected lot.
3. Secondary and micro nutrients are deficient if the analysis of an official sample is below the guarantee by an amount exceeding the values in **Table 7.**

Table 6. Plant nutrient guarantee levels

GUARANTEE	Nitrogen (N)	Available Phosphate (P_2O_5)	Potash (K_2O)
	percentage (%)		
04 or Less	0.41	0.67	0.41
05	0.51	0.67	0.43
06	0.52	0.67	0.47
07	0.54	0.68	0.53
08	0.55	0.68	0.60
09	0.57	0.68	0.65
10	0.58	0.69	0.70
12	0.61	0.69	0.79
14	0.63	0.70	0.87
16	0.67	0.70	0.94
18	0.70	0.71	1.01
20	0.73	0.72	1.08
22	0.75	0.72	1.15
24	0.78	0.73	1.21
26	0.81	0.73	1.27
28	0.83	0.74	1.33
30	0.86	0.75	1.39
32 or More	0.88	0.76	1.44

- *For guarantees not listed, calculate the appropriate value by interpolation.*
- *Plant nutrient values will be calculated on the basis of the price documented in the inspection lot.*

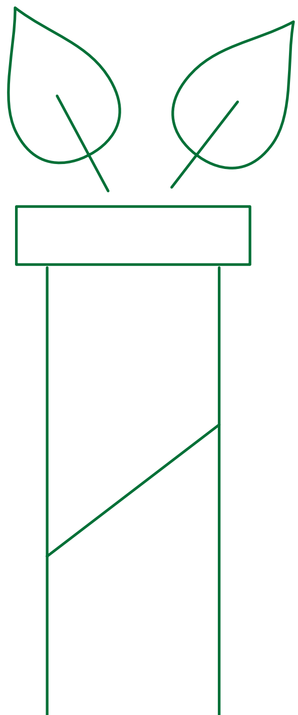


Table 7. Secondary and micro nutrient guarantee levels

ELEMENT	INVESTIGATIONAL ALLOWANCE		
	Percent (%)	Percent (%) of Guarantee	
Calcium	0.2	+	5
Magnesium	0.2	+	5
Sulfur	0.2	+	5
Boron	0.003	+	15
Cobalt	0.0001	+	30
Molybdenum	0.0001	+	30
Chlorine	0.005	+	10
Copper	0.005	+	10
Iron	0.005	+	10
Manganese	0.005	+	10
Sodium	0.005	+	10
Zinc	0.005	+	10

- *The maximum allowance when calculated in accordance with the above shall be one percent.*
- *Plant nutrient values will be calculated on the basis of the price documented in the inspection report for the inspected lot.*

Regulation 31

Plant Nutrient Guarantee Levels

ORDER OF DECLARATION	NUTRIENT	MINIMUM PERCENT CLAIMABLE
1	Calcium (Ca)	1.0000
2	Sulfur (S)	1.0000
3	Magnesium (Mg)	0.5000
4	Boron (B)	0.0200
5	Chlorine (Cl)	0.1000
6	Cobalt (Co)	0.0005
7	Copper (Cu)	0.0500
8	Iron (Fe)	0.1000
9	Manganese (Mn)	0.0500
10	Molybdenum (Mo)	0.0005
11	Sodium (Na)	0.1000
12	Zinc (Zn)	0.0500

Regulation 33

Maximum allowable heavy metal limit

HEAVY METAL	MULTIPLIER		TOLERANCE
	ppm per 1% P_2O_5	ppm per 1% micro nutrients	milligrams per kilogram of biosolids or compost products-dry weight basis
Arsenic	13	112	75
Cadmium	10	85	85
Cobalt	136	2,228 (a)	-
Copper	-	-	4,300
Lead	61	463	840
Mercury	1	6	57
Molybdenum	42	300(a)	75
Nickel	250	1,900	420
Selenium	26	180	100
Zinc	420	2,900(a)	7,500

- *The maximum allowance when calculated in accordance with the above shall be one percent.*
- *Plant nutrient values will be calculated on the basis of the price documented in the inspection report for the inspected lot.*

Regulation 34

Maximum allowable variation of nutrient content

TYPE OF FERTILIZER	TOLERANCE
Single nutrient fertilizers	N/A
...With up to 20% nutrient content	Maximum 0.3 units
...With more than 20% nutrient content	Maximum 0.5 units
Complex fertilizers	Maximum 0.5 of units for individual nutrients and maximum of 2% for all nutrients combined
NPK blends	Maximum of 0.8 units for individual nutrients and maximum 2.5% for all nutrients combined

Section 91. (1) of Act 803

A person shall not sell any fertilizer in a package where the fertilizer is short in weight by more than one percent of the weight indicated on the package.

Testing

To ensure that the blended products have the required balanced nutritional content, blenders are mandated to take samples of every batch of their products, store them for a minimum of six months, test them internally, and send them to an accredited external independent testing laboratory. In Ghana, tests can be conducted at a PPRSD-designated laboratory. The product should not be discarded after testing, store them for a minimum of six months.

3. Storage And Dispatch of Blended Products

3.1 Storage of Blended Fertilizer

3.2 Dispatch of Blended Fertilizer

3. Storage And Dispatch Of Blended Products

Fertilizers are made up of minerals and elements that do not deteriorate with time. Therefore, they can be stored for long periods. Dry granular fertilizers can be stored indefinitely if they are not exposed to moisture, which can cause caking or mould growth, and if they are kept in a manner such that rodents cannot chew holes in the bags. Liquid or organic fertilizers can last up to eight years, and liquid mineral fertilizers can last for up to ten years.

3.1 Storage Of Blended Fertilizer

After bagging and stitching, the blended products are taken to a storage location for bagged fertilizer or loaded directly onto trucks for dispatch, as provided for under Regulation 20 of the L.I. 2194, relating to warehousing and storage of fertilizer. In addition, every blender should have an internally developed set of SOPs for storing blended products. The following serves as guidance for the storage of blended products.

3.1.1 Guidelines for Storage of Blended Fertilizer

- General: fertilizer products in an enclosed space for safety and security and to ensure they are not exposed to weather or direct sunlight. Provide controlled access to the finished products. Use non-combustible materials (e.g. concrete, steel) for the construction of the storage facility. The floors of the storage area should be of even surface, level, dry, and free from potholes.
- Cover stored fertilizer with plastic polyethylene sheets to prevent contamination from dust, humidity, rainwater, or other raw materials.
- Ensure the storage is in a clean environment, free of dust and dirt.
- Use bags lined with a waterproof material, e.g. plastic, to prevent moisture exchange, which will damage the bagged product.
- Sample blended products. Label samples with the date and batch number and keep them as specified in Section 2.10.1.1. See Annex P for more on sampling.
- Provide signs or labels indicating the type of product in the fertilizer bin (fertilizer storage area).
- Store dry products separately from liquids to prevent wetting from a liquid spill.
- Do not store products that react in any manner side by side or close to each other. Keep the fertilizer away from any flammable material. Ensure there is a distance of at least 5 metres between bulk and bagged materials. Most nitrogen fertilizers decompose when exposed to high heat (150ºC) and develop toxic nitrogen. Other fertilizers can develop carbon and sulphur oxides when exposed to high heat.
- Practise a good stock management system, i.e. "first in, first out." Store the bags according to internal SOPs, i.e. in a manner that will allow for easy and safe access when loading onto dispatch trucks or for monitoring purposes. Bags should not be stacked at more than 5 metres high; if they are stacked too high, the stack can become unstable and collapse. Store bags at least 1 metre away from building eaves, beams, and walls. Bulk bags can be stacked up to three sacks high. Bundle and dispose of used bags in an approved landfill. In some cases, fertilizer blenders sell used bags to local furniture makers who thoroughly clean the bags and reuse them as filling or padding for handmade furniture, e.g. sitting room couches. Blend only what is required when it is required. This helps prevent unnecessary long-term storage.

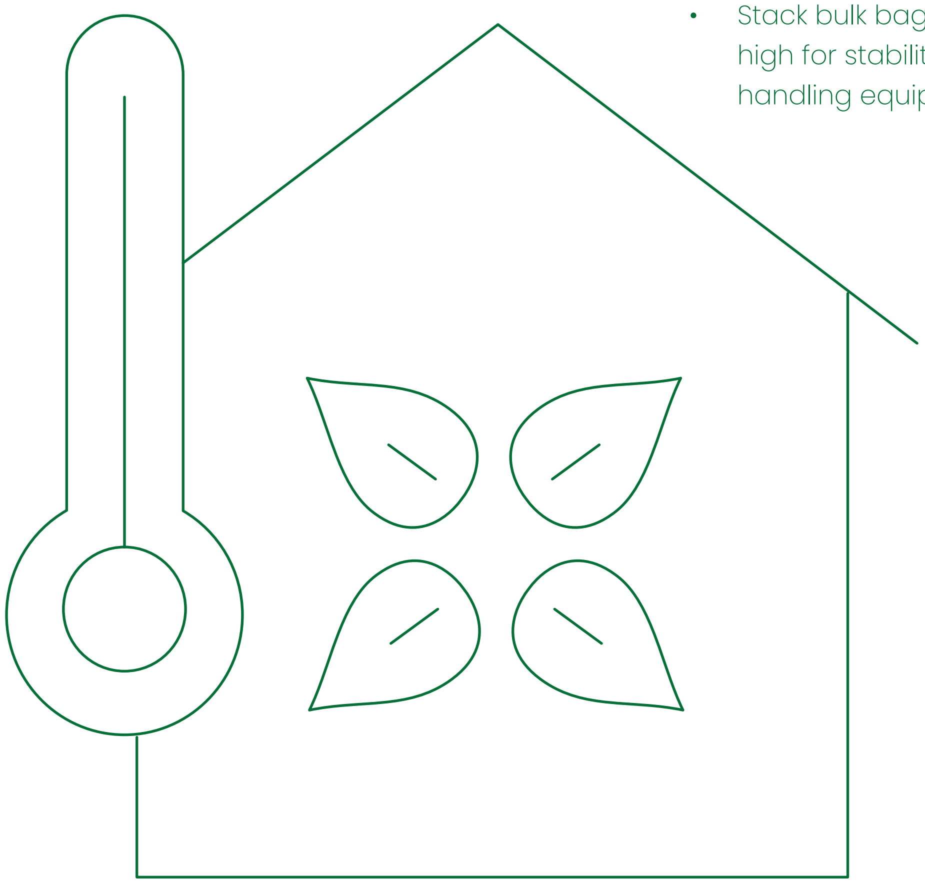
- Clean any spills immediately.
- Establish an emergency response plan for the site.

For Indoor Storage

- Keep storage temperatures between 5° and 30°C because some types of fertilizers are sensitive to extremely low or high temperatures. In Ghana, where temperatures can reach above 30°C, well ventilated facilities and temperature control are highly recommended.
- Use pallet racking for blended fertilizer storage to keep bags off the floor and safe from water. Avoid double stacking. Ensure the base is firm, especially when placing pallets on top of each other.

For Outdoor Storage

- Store blended fertilizer on a dry, well-drained, smooth, and raised floor.
- Use pallets in good condition to prevent direct contact with the ground or rainwater.
- Use empty pallets to form a layer on top of the stack pile before covering it with plastic sheeting. This will help preserve the quality of the product by preventing excessive heat from coming in direct contact with the product. Covering the stacks prevents bags from getting dirty but the sheeting must be tightly secured at the bottom.
- Protect the sheeting with empty pallets so birds cannot damage the sheets and bags.
- Restack the products in any tilted stacks immediately. Ensure covered stacks are stable before unsheeting. Be aware of any algae on sheets, which can create a fall hazard. Sheeting and unsheeting of stacks should be done in good weather conditions.
- Stack bulk bags no more than three pallets high for stability and safety of personnel and handling equipment.



3.2 Dispatch Of Blended Fertilizer

In Ghana, fertilizer blends are usually dispatched in bags. The most common bag sizes are 50 kg and 25 kg. The success of a fertilizer operation depends not only on completing the blending and bagging activities but is also linked to activities after bagging. This includes how the blended products are handled at the stitching lines through dispatch. This section will discuss how blended products should be handled.

3.2.1 Guidelines for Dispatch of Produced Blends

Transporting blended fertilizer creates opportunities along the line for the product to deteriorate before reaching the final user. As such, handling and transporting it in a safe manner is of utmost importance.

To maintain the quality of blended fertilizer during its transportation, consideration must be given to the properties of the raw materials that made up the blends, the type of fertilizer blend, how it is transported (in bulk or bags), the correct handling procedures, and the prevailing weather conditions.

Every blender should have an internally developed set of SOPs for dispatching blended products. The following can serve as general guidance:

1. Inspect blended products in bays/bins before dispatch to ensure what is being dispatched is exactly the correct request.
2. Load trucks according to the client's preference. Loading should be done in a manner that is easy, smooth, and efficient:

    a) Use inclined conveyors long enough to reach the truck beds from the stitching lines when loading loose bags directly onto trucks

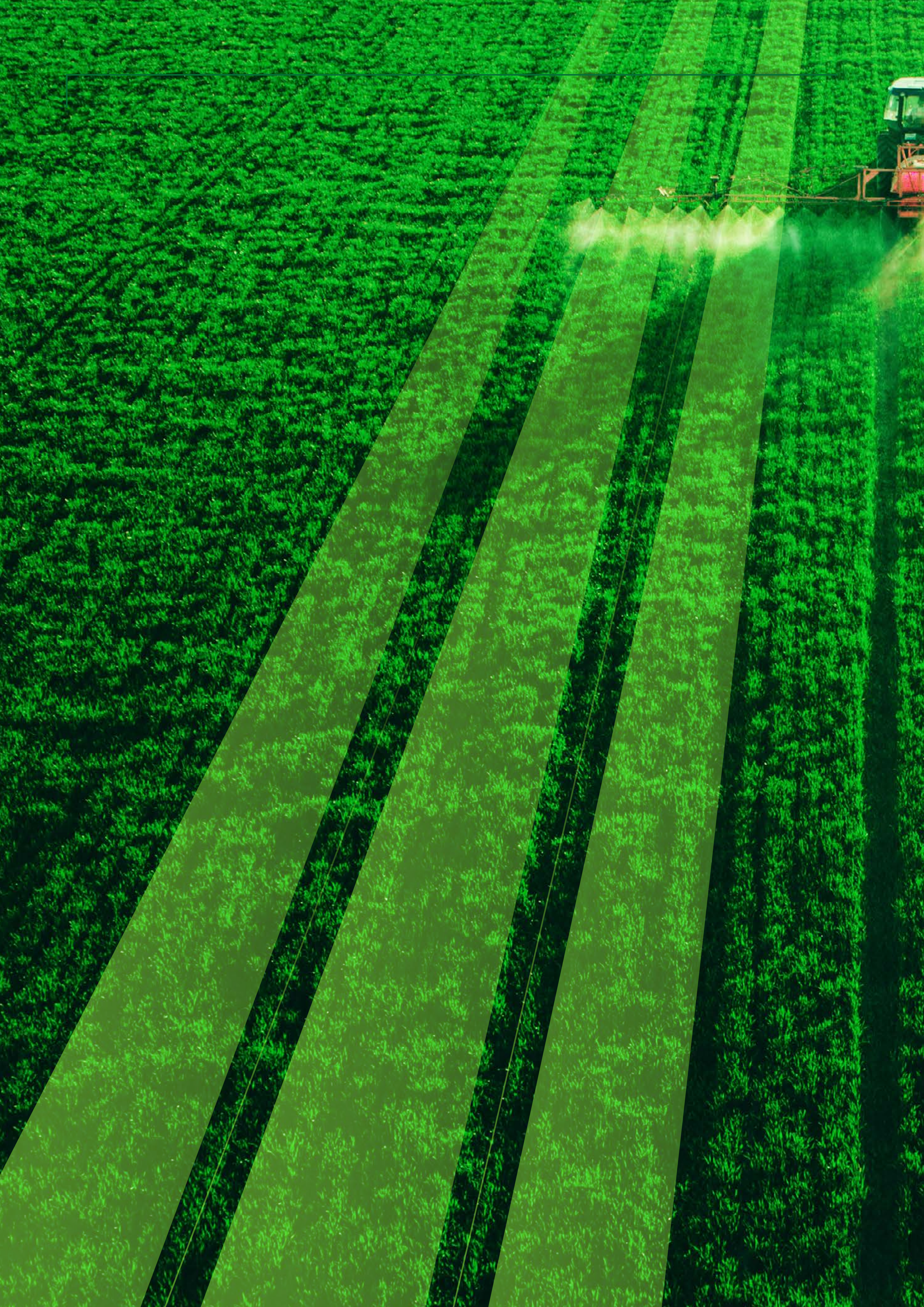
    b) Use forklifts when loading loose bags onto pallets.

    c) The truck needs to be off, parked, and chucked while loading is going on

    d) Make sure the truck bed should be clean, free from oil leakages and free of any sharp items that can tear the bags.

    e) The truck bed should be even, free of holes, and exposed metals.

    f) After loading the fertilizer on the truck, it should always be covered with tarpaulin (sheeting).
3. Take a sample from every batch, analyse it, and keep it for traceability.



4. Record Keeping

4.1 Guidelines for Record Keeping

4.2 Forms of Record Keeping

4. Record Keeping

As a good practice, accurate records must be kept for internal analysis and planning purposes as well as statutory reporting (Regulation 22 of L.I. 2194). These require you to not only keep good records but also provide accurate documentation. Every blender should consider becoming certified because many larger fertilizer customers now require that bulk blenders be certified.

To be certified requires another level of record keeping and documentation. A coordinator must be designated in the operations primarily to handle all the record-keeping needed and work with the certifying agencies. The entire team will need to be trained on safe handling practices, and this must be documented.

4.1 Guidelines for Record-Keeping

Every blender should have an internally developed set of SOPs for accounting and record keeping. The following serve as guidelines:

1

When receiving raw materials:

a) Weigh all inbound raw materials across a certified weighbridge.

b) Capture and tally the corresponding weights accurately per shift.

c) Audit all inbound cargo. This should be done by a certified external surveyor/auditor to ascertain the quantity of product received at any given time.

d) Compare weighbridge and survey figures and act immediately if any anomaly is more than the prescribed tolerance limit.

2

Before blend production:

a) Compute blend calculations correctly per batch so that too much raw material is not used and hence lost within the system.

b) Record these figures accurately per batch and work back-to-floor stock balance on every shift.

3

During blend production:

a) Accurately tally the number of raw materials taken from product bays or bins into blending plants to ensure quantities deducted from storage bays or bins during production are in accordance with pre-calculated weights.

b) Ensure the automated scales capture the weight for each bag, then manually weigh random bags per batch. This will ensure that bag weights are accurately matched to how much was taken out of storage and accounted for at the post-production stage.

4

After blend production:

a) Do a variance analysis: Calculate the total weight of every batch and work the weights back to the amount taken out of storage. Compare this with the amount left on the floor to maintain total product stewardship in terms of quantities.

Automated systems are encouraged because of ease of access, data safety and security. However manual copies can be kept as backup in case of system failures.

4.2 Forms of Record Keeping

4.2.1 Production Records

Keeping records of your hourly, daily, weekly, monthly, and annual production is critical to analyse what worked and what did not. Combining these records with the cash flow records will enable a blender to determine whether it would be more profitable to use known quantities of raw materials, buy at a certain price, or practice bulk blending and whether the same quantities of production output could be achieved while minimising expenses and selling at higher prices.

The key to profitability is to buy raw materials in bulk when international or market prices are lower than usual, keeping the blending operation's overhead costs and expenses as low as possible without compromising the quality of the product, and selling the blends when market prices are higher than usual. Production records should be kept for each type of fertilizer raw material and blend formulation. Raw material receipts and information on blend production and dispatch to customers should be kept.

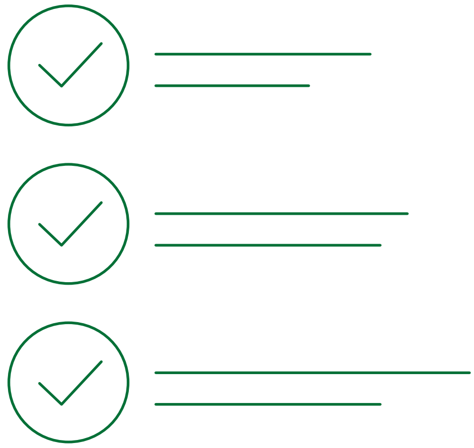
4.2.2 Quality Records

A fertilizer blending operation without quality records exposes itself to possible claims that may arise from clients. Therefore, to protect the integrity of the operation and ensure financial losses are not unnecessarily incurred to claims, these records should be judiciously kept and maintained.

Records, such as CoA, SDS, building construction certificates, building inspection certificates, plant calibration schedule/register, samples of blend products, results of analysed blend samples, mobile equipment maintenance schedule/register, Safety, Health, Environment, Risk, And Quality (SHERQ) registers, and the dispatch register, should be attended to in a timely manner and kept safe. Using a fully automated plant helps with one of the most essential quality records, i.e. bag weights. Erroneous bag weights can lead to customer dissatisfaction and loss of raw material stocks. Refer to Section 2.10 for more information on quality control.

4.2.3 Logistics and Warehouse Records

Fertilizer blending operations involve many moving parts, i.e. raw materials, finished goods, personnel, and equipment. Keeping track of each of them can be difficult, but this is extremely important for effective management of an operation. Every operator should have internally developed logistics and warehousing records that are unique to their operation and specific to the type of plant they have. The following serves as a guide:



1. Create a building inspection and maintenance checklist.
2. Create a raw material receipt and storage checklist.
3. Create a production checklist.
4. Create a finished product storage and inspection checklist.
5. Create a sweepings or spillage storage checklist.
6. Create a dispatch plan.
7. Create a mobile equipment inspection and maintenance checklist.
8. Assign resources to each task and align these checklists and plans to Section 3.

4.2.4 Financial Records

A detailed check register will enable the operator and the accountant to produce several financial records. With the additional information, income statements, balance sheets, and performance ratios that will enable an expert analysis of the operations can be produced. A cash flow is a record of all income and expenses listed by category.

For example, a category for each type of fertilizer sold would be required, i.e. blend or straight. A cash flow record is dynamic because all monthly income and expenses in the applicable categories are recorded. A record of cash flow for a year will enable certain decisions, such as when additional cash is needed or when certain bills are due, to be made easily.

An income statement combines some of the items from a cash flow record into broader categories. The income statement is where accrual adjustments, considering changes in inventory, are made. A balance sheet is a snapshot of the operation on a given day. It is usually completed at the end of a fiscal year to enable consistent comparisons of the operation. The information from a balance sheet and income statement can be used to calculate specific ratios for financial analysis.

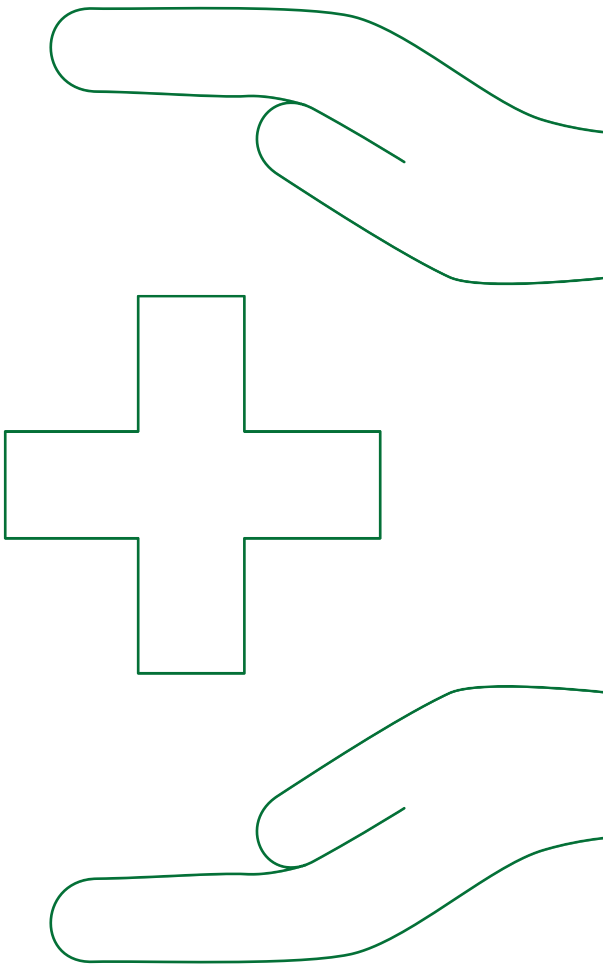
4.2.5 Maintenance Records

Every operator should have internally developed plant and mobile equipment maintenance records that are unique to their operation and specific to the type of plant they have. This will keep track of all the maintenance carried out in and around the plant, which is beneficial in implementing the predictive maintenance approach recommended in this manual.

For effective maintenance record keeping, a schedule of maintenance activities by shift, week, and month and at shutdown should be developed for plant components, such as macro hoppers, under-bin conveyors, pre-coating blender, micro hoppers, fines screener, bagging machine, product blender, oversize screener, stitching conveyor, stitching machines, and palletizing conveyor. The internally developed maintenance checklist should be in alignment with the plant and mobile equipment manufacturers' technical manual. Refer to Section 2.9.3 for more on plant maintenance.

4.2.6 Safety, Health, Environment, and Risk Records

In a fertilizer blending operation, keeping safety, health, environment, risk, and quality records is very important. Every operator should have internally developed SHERQ records that are unique to their operation and specific to the type of plant they have. These records should follow certain principles, processes, and guidance.



Principles

These outline the need for SHERQ management:

1

Plan, Do, Check, Act

2

Policy, organisation, planning and implementation, measuring performance, auditing, and reviewing performance.

Processes

These establish SHERQ management:

- Risk assessment
- Work permit
- Modifications management and change
- Incident reporting
- Incident investigation and follow up
- Handling chemicals
- Process and electrical safety
- Confined space emergency response
- Safety auditing and review
- Behavioural safety

Guidance

These are daily SHERQ management requirements:

- Housekeeping
- Leader safety walk
- Handling chemicals
- Working at height (fall protection)
- Lifting operations
- Forklift and loader
- Safety machinery operation
- Portable hand and power tools
- Manual handling,
- Office safety
- Driver safety
- Transport safety

5. Conclusion & Recommendations

5.1 Conclusion

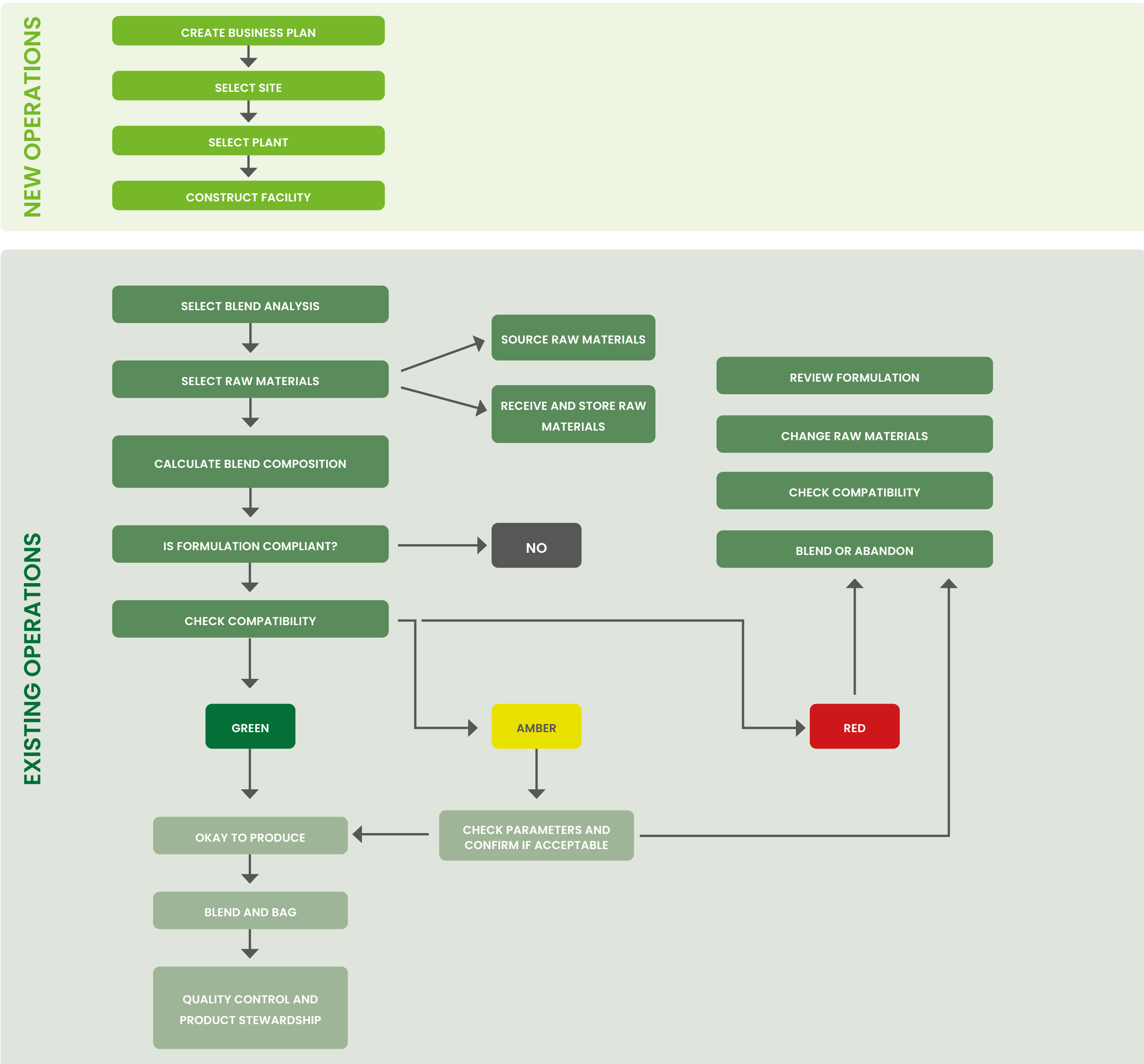
5.2 Recommendations

5. Conclusion And Recommendations

5.1 Conclusion

Strict adherence to the guidelines in this manual will ensure that operators produce quality fertilizer blends. By providing foundational guidelines that can be built upon, each section of this manual details steps that can positively affect the quality of bulk blends. **Figure 6** illustrates and summarises these steps.

Figure 6. Summary of production of quality fertilizer blends



Adapted from Fertilizers Europe, 2014

5.2 Recommendations

To produce quality fertilizer blends, the following steps are recommended.

The fertilizer blending operator should:

1. Select a suitable location for the operation, source the right raw materials from credible suppliers so that the quality and quantity of the nutrient contents are guaranteed, blend and bag to the prescribed standard, carry out plant maintenance as prescribed, and adhere to good general housekeeping.
2. Receive and store raw materials such that their compatibility is taken into consideration:
    - Incompatible raw materials should not be stored close to each other or used in blends together because the quality of the final blend will be compromised.
    - Raw materials with limited compatibility should be assessed for their chemical-, physical-, and safety-based compatibility before being stored in their designated bays/bins or before being used in blends.
3. Select a good bulk blending plant. The key points to note are performance in terms of speed, accuracy, capabilities, simplicity of operation (both types of plants need capable software to run the system and interact with the accounting software), budget, and space requirements.
4. Store produced blends in a manner that ensures their quality will not be compromised and dispatch is seamless.
5. Employ good accounting and record-keeping practices that cover the entire operation.
6. Adhere to the following quality control measures:
    - Select raw materials with known nutrient content and closely matched particle sizes.
    - Understand the chemical, physical, and compatibility properties of the raw materials.
    - Carry out sampling and physical testing of both the raw materials and finished blends.
    - Utilise bags with an inner lining and transparent sides when bulk blending. The transparent sides enable visual inspection of the quality of blends contained therein **(Figure 7)**.

Figure 7. Fertilizer bags with polyethylene liner and transparent sides

Table 8. Indicative bag characteristics

FERTILIZER BAG CHARACTERISTICS	
Product	• Fertilizer packaging bag • Laminated polypropylene woven sack • Polyethylene liner • Transparent sides – recommended
Material	• 100% virgin polypropylene
Size	• 10 kg: L 610 mm * W 350 mm • 20 kg: L 760 mm * W 450 mm • 25 kg: L 800 mm * W 450 mm • 50 kg: L 980 mm * W 580 mm
GSM	• 40 gsm - 80gsm • 75 gsm recommended
Description	• High tensile strength • Withstands falls and friction • Dimensional stability • Good printing surface • Compliance contact

1. Capacity-building exercises should be carried out at least annually to boost and sustain the technical and business know-how of all bulk blending players in the region.
2. Bulk blenders should be equipped to carry out in-house testing and analysis of raw materials and blend analysis.
3. Fertilizer blends not meeting the stipulated tolerances should result in penalties and prosecution.
4. All blenders should be properly registered and should register their fertilizer blends according to the stipulations in the country in which they operate.
5. The roles and responsibilities of each sector should be clearly defined, e.g. the government is to create an enabling environment and encourage private sector-led fertilizer operations.

NB:

It is recommended that industry players use this guide in their operations to help them meet the requirements set out by the PPRSD of the Ministry of Agriculture.

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Annexes

A. Business Plan Details

The following is some of the important information that should be captured in a business plan. However, as previously mentioned in Section 2.1, deferral should be made to the experienced consultant hired to prepare the document. This serves only as a guide.

General Assumptions Page

General Information
- Model name
- Model description
- Major currency
- Currency symbol

Dates and Period
- Projection period
- Base month
- Preoperative period (construction, installation, and commissioning)
- Effective start date

Date Assumptions
- Months in the year
- Days in a year
- No. of quarters in a year
- No. of days for downtime, routine maintenance, and others
- No. of days plant is operational per year
- No. of days in a month
- No. of work hours per shift
- No. of shifts in a day

Capacity Utilisation
- Installed plant capacity
- No. of plants to be installed
- Year 1 – Year X capacity utilisation
- Utilisation spread between product blends (for product type A-Z)

Output Mix
- Quantity (kg) of raw material A-Z

Input Prices
- For raw material A-Z

Output Prices
- For product type A-Z

Tax Rate
- Country Specific

Equity Discount Rate
- Country Specific

Bank Lending Rate
- Country Specific

CAPEX, DEVEX, OPEX
- Plant, building, and operational running costs

Unit Cost Computation
- Ex., factory cost for product type A-Z

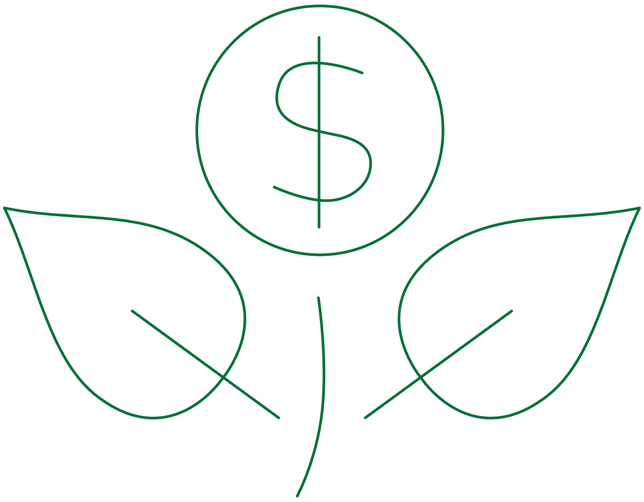
Unit Profit Computation
- Selling price for product type A-Z

Financial Summary Page

1. Profits and Cash Flow
- Revenue
- Gross profit
- Overhead expenses
- EBITDA
- Interest payment
- Profit after tax
- Cash generated from operations

2. Balance Sheet

- Fixed assets
- Current assets
- Liabilities
- Net assets
- Shareholders' funds



3. Ratios

- Return on average equity
- Gross profit margin
- EBITDA margin
- Overhead expenses margin
- Net income margin

B. Indicative Cost Estimates Required To Set Up A Turnkey Bulk Blending Operation

Facility Construction

	ESTIMATED BUILDING COST RANGE	
THROUGHPUT CAPACITY	BATCH BLENDING & BAGGING SYSTEM	CONTINUOUS BLENDING & BAGGING SYSTEM
≤ 30,000 mtpa	≤ $1,000,000 - $5,000,000	N/A
30,000 - 70,000 mtpa	≤ $5,000,000 - $10,000,000	≤ $5,000,000 - $10,000,000
70,000 - 150,000 mtpa	≤ $10,000,000 - $15,000,000	≤ $10,000,000 - $15,000,000
150,000 - 200,000 mtpa	≤ $15,000,000 - $20,000,000	≤ $15,000,000 - $20,000,000
Over 200,000 mtpa	≤ $20,000,000 - over $20,000,000	≤ $20,000,000 - over $20,000,000

mtpa: metric tons per annum

Additional facility requirements for production

EQUIPMENT	1-30 MTPH	31-70 MTPH	71-150 MTPH	150-OVER 200 MTPH
Front-End Loader (FEL)	Maybe	Maybe	Yes	Yes
Modified FEL	Yes	Yes (Multiple)	No	No
Forklifts	Yes	Yes (Multiple)	Yes	Yes
Loading Bays	Yes	Yes	Yes	Yes
Receiving Conveyors	Maybe	Maybe	Yes	Yes
Weighbridge	Yes	Yes	Yes	Yes

mtph: metric tons per hour

Notes: Facility Construction Section

- Factors influencing facility construction costs include planned throughput per annum, planned throughput cycles per annum, market demand, client's liquidity, etc.
- Throughput is defined as the amount of raw materials passing through the production facility, i.e. raw materials received and produced blends dispatched.
- Cost of facility construction include buildings (main warehouse, external buildings, etc.) and external works (truck parking bays for customers, warehouse loading bays where applicable, services buildings, etc.).
- Cost for facility construction includes a weighbridge system.
- Cost of a receiving conveyor system can be over $200,000, depending on the size and anticipated volume throughput.

Raw Materials

RAW (RM) COMMONLY USED IN WA	THROUGHPUT CAPACITY	AV RM Price/mt	PRICE ESTIMATE for RMs	PRICE ESTIMATE/CYCLE (e.g., 4 cycles/year)
Urea, DAP, MAP, MOP, AS, NPK, Filler, etc.	5,000 mtpa	$715	$3,575,000	$893,750
	10,000 mtpa		$7,150,000	$1,787,500
	20,000 mtpa		$14,300,000	$3,575,000
	50,000 mtpa		$35,750,000	$8,937,500
	100,000 mtpa		$71,500,000	$17,875,000

Notes: Raw Materials Section

- Raw material prices were based on the global average price, as of January 2022, for urea, MAP, DAP, and MOP. Filler price in Nigeria was adopted.
- Cost of raw materials required was calculated by multiplying estimated throughput tonnages per annum by the average cost of the raw materials considered.
- Due to the high cost of the raw materials, they should be procured in throughput tranches/cycles, e.g. four tranches/cycles per company's financial year.

Source: https://farmpolicynews.illinois.edu/2022/01/fertilizer-price-update-and-iowa-crop-production-cost-estimates-for-2022/.

C. Indicative Cost of Blending Plants Of Various Capacities

ESTIMATED PLANT COST RANGE		
BULK BLENDING CAPACITY	BATCH BLENDING AND BAGGING SYSTEM	BATCH BLENDING AND BAGGING SYSTEM
1-30 mtph	≤ $100,000 - $300,000	N/A
31-70 mtph	≤ $300,000 - $500,000	$300,000 - $700,000
71-150 mtph	≤ $500,000 - $1,000,000	≤ $700,000 - $1,200,000
150-200 mtph	≤ $1,000,000 - $1,500,000	≤ $1,200,000 - $1,500,000
Over 200 mtph	over $1,500,000	over $1,5000,000

SECONDARY COSTS	
Forklift	± $40,000
FEL	± $100,000
FEL- Modified Forklift	± $50,000

Notes: Bulk Blending Plant Section

- Plant cost estimates as of January 2022.
- The price ranges for the plants are NOT set in stone and may vary significantly based on various international and country specific factors.
- The price ranges for the plants were taken from manufacturers in America, Canada, China, Europe, India, and South Africa.
- Delivery time for purchased plants to West Africa ranges from 14 to 40 weeks.
- Types of batch plants: vertical auger blender type; horizontal drum blender type; paddle blender type; tower blender.

- Types of continuous plants: continuous blender by weighing control; continuous blender by volumetric control.
- There are also combined systems, whereby a setup consists of a combination of a batch and continuous system.
- If considering a batch plant system, it is advisable to use a tower-style plant for production of over 60 mtph.
- It is NOT advisable to use a continuous system for production of under 30 mtph, hence the N/A comment

D. List of Some Bulk Blending Plant Manufacturers

AFRICA

Bagtech Fertilizer Management and Handling Solutions
https://bagtechint.com/

EUROPE

EMT
https://emt.tech/

NORTH AMERICA

Adams Fertilizer Equipment
https://www.adamsfertequip.com/

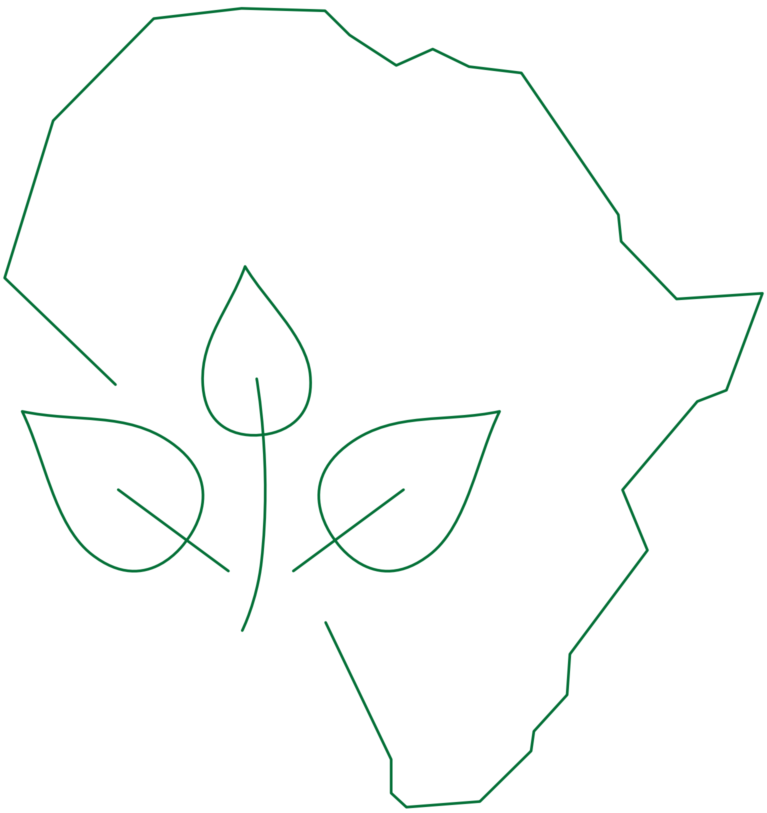
AGI Fertilizer Systems/Yargus
https://aggrowth.com/en-us/fertilizer

Doyle Equipment Manufacturing
https://www.doylemfg.com/

Murray Equipment Inc.
https://www.murrayequipment.com/target-markets/dry-fertilizer.html

Ranco Fertiservice Inc.
https://www.rancofertiservice.com/

Sackett-Waconia
https://www.sackettwaconia.com/



E. Examples of Each Type Of Plant

Continuous System

Dynamic weight control system

Mesh DCS multi-blending system

Batch System

Tower blending system

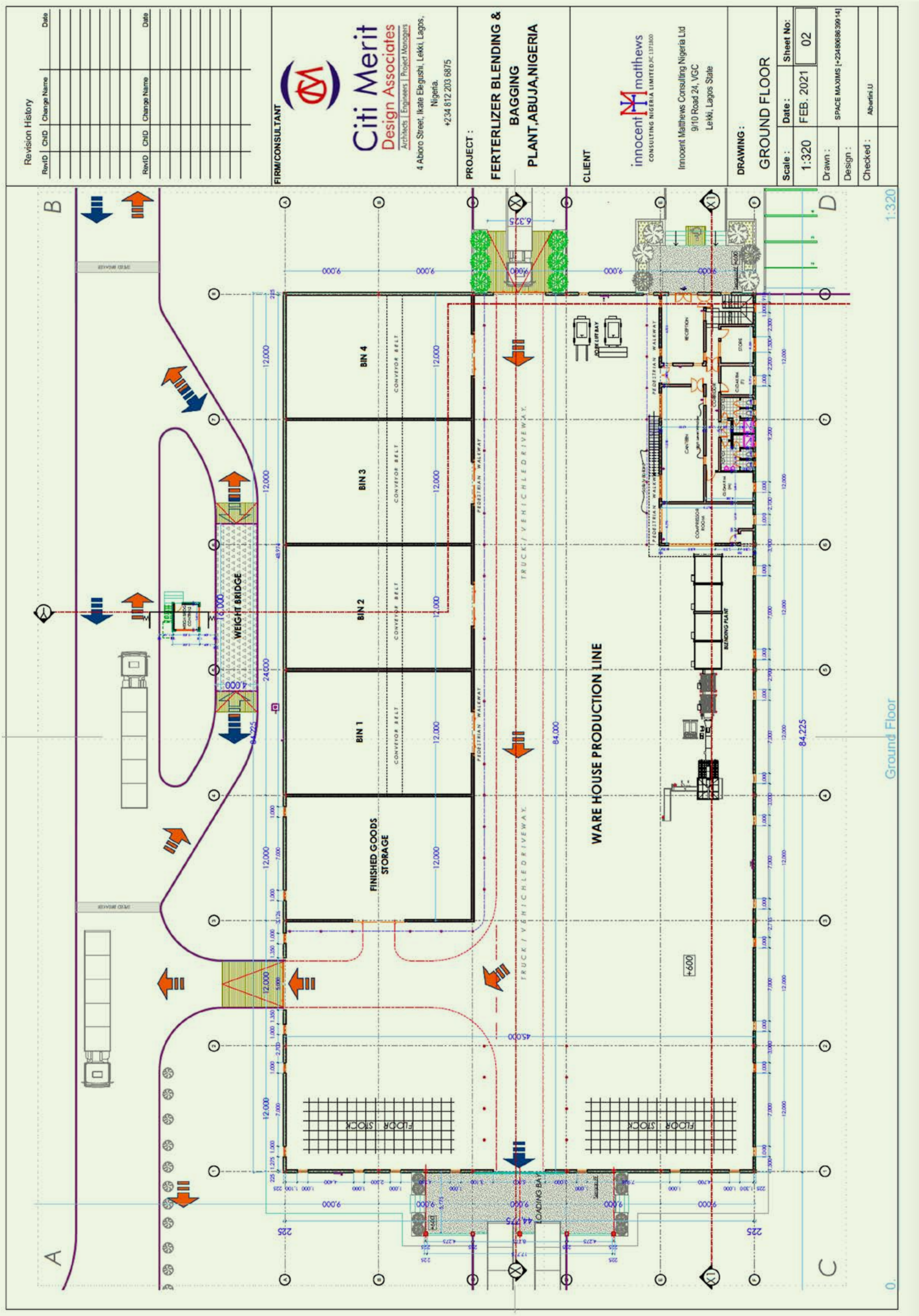
Mix Plants

Auto Batch

On-Farm Blender

Source: CropLife IRON, 2019

F. Indicative Architectural Layout of A Bulk Blending Facility



G1. Nitrogen And Phosphorus Manufacturing Facilities In Ecowas, 2022

#	Country	Plant Site	Company	Product	Year Est.
1	Burkina Faso	Bobo Dioulasso	Faso Fert	Crushed Dolomite	2022-2023
2	Burkina Faso	Diapaga	Société d'Exploitation des Phosphates du Burkina (SEPB)	Natural Phosphate Rock	2012
3	Mali	Bourem	Sangoye	Granular Phosphate	2023–2024
4	Mali	Bamako	Toguna Agro Industries – Tilemsi	Natural Phosphate Rock	2009
5	Nigeria	Bayelsa	Brass Fertilizer	Granular Urea	Unknown
6	Nigeria	Ibeju Lekki, Lagos State	Dangote Fertilizer Limited	Granular Urea	2021
7	Nigeria	Eleme, Rivers State	Indorama Eleme Fertilizers & Chemicals Ltd – Phase 1	Granular Urea	2016
8	Nigeria	Eleme, Rivers State	Indorama Eleme Fertilizers & Chemicals Ltd – Phase 2	Granular Urea	2021
9	Nigeria	Onne, Rivers State	Notore Chemical Industries Plc	Granular Urea	2005
10	Senegal	Dakar	Amafrique SUARL	Granular Phosphate	2023–2024
11	Senegal	Dakar	Industries Chimiques du Sénégal (ICS)	Phosphate Rock, Phosphoric Acid, DAP, NPK, Gypsum	1976
12	Senegal	Matam	Société d'Études et de Réalisation des Phosphates (SERPM)	Natural Phosphate Rock	2007
13	Senegal	Matam	Société Minière de la Vallée du Fleuve (SOMIVA)	Phosphate Rock	2008
14	Togo	Kpémé	Société Nouvelle des Phosphates du Togo (SNPT)	Phosphate Rock	1961

Source: AfricaFertilizer.org and IFDC, 2022

G2. Organic Fertilizer Manufacturing Facilities In Ecowas, 2022

#	Country	Plant Site	Company	Year Est.
1	Benin	Allada	Bio Phyto	2013
2	Burkina Faso	Ouagadougou	Arom-H/Sol Fertile	2014
3	Burkina Faso	Ouagadougou	Faso Biogaz	2015
4	Côte d'Ivoire	Adzopé	Éléphant Vert Côte d'Ivoire	2014
5	Ghana	Adjen Kotoku	Accra Compost & Recycling Plant (ACARP)	2012
6	Ghana	Akorley, Somanya	JVL-YKMA Recycling Plant	2020
7	Ghana	Ashaiman	Safisana	2016
8	Ghana	Borteyman, Tema	JVL Fortifier Compost Plant	2017
9	Ghana	Jamestown, Accra	Ga Mashie Aerobic Compost Plant	2013
10	Ghana	Mpasatia/Nkawie	New Okaff Industries Limited	2014
11	Mali	Bamako	Orgafert	2018
12	Mali	Bamako	PROFEBA	2017
13	Mali	Ségou	Éléphant Vert Mali	2018
14	Nigeria	Kaduna	Dharul Hijrah Fertilizer Company Ltd	2016
15	Nigeria	Kano	Excel Standards Ltd	2013
16	Senegal	Dakar	Biotoss	2017
17	Senegal	Dakar	Éléphant Vert Sénégal	2018

Source: AfricaFertilizer.org and IFDC, 2022

G3. Soil Supplement And Micro nutrient Manufacturing Facilities In Ecowas, 2022

#	Country	Plant Site	Company	Product	Year Est.
2	Ghana	Takoradi	Carmeuse Lime Products GH Ltd	Lime Supplements	2020
3	Nigeria	Kaduna South	Cybernetics Nigeria Ltd	Micronutrients	1985

Source: AfricaFertilizer.org and IFDC, 2022

H. Summary of Required Plant Nutrients

19 PLANT NUTRIENTS

For Improving And Protecting Plant Health

Plants use minerals present in the soil and water in order to grow and flourish. Just like with humans, if they don't get enough of these nutrients it can seriously affect their health. Ensuring proper plant nutrition by using fertilizers (organic and mineral) to supplement the nutrients already available in the soil is essential for plant health.

Here's a look at 19 nutrients that can benefit plant health (in addition to improving yields):

NITROGEN
Nitrogen is an essential component of amino acids for building proteins, nucleic acids and chlorophyll which converts the sun's energy into sugars. It is vital for plant metabolism, growth and health.

PHOSPHORUS
Phosphorus is vital for energy storage and transfer and membrane integrity in plants. Particularly important in early growth stages, it promotes tillering, root development, early flowering and ripening

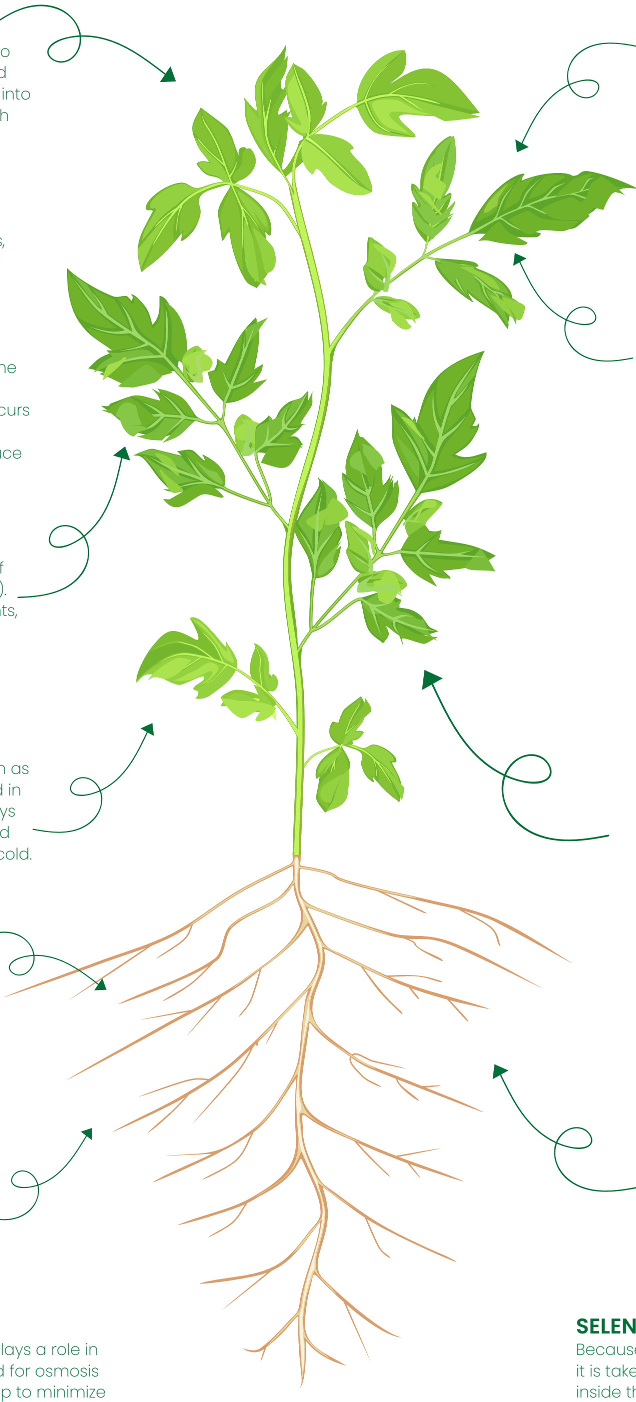
COBALT
Cobalt is an essential component of some enzymes and co-enzymes that can affect the growth and metabolism of plants. It is also necessary for Nitrogen (N) fixation which occurs within the nodules of legumes. Cobalt can increase seeds' drought tolerance and reduce plant stress

POTASSIUM
Potassium has major functions in enzyme activation, transpiration and the transport of assimilates (the products of photosynthesis). It helps plants to retain water during droughts, provides strength to plant cell walls and decreases susceptibility to diseases and insects.

CALCIUM
Calcium is needed for biomembrane maintenance. It helps in cell wall stabilization as an enzyme activator, in osmoregulation and in the cation-anion balance and thus also plays important roles in resistance to diseases and abiotic stresses such as drought, heat and cold.

MAGNESIUM
Magnesium is central to the production of chlorophyll which is needed for photosynthesis and healthy green leaf tissue. It reduces crop stress caused by exposure to the sun and high temperatures, while a deficit can often cause stunted growth.

BORON
Boron is required for cell wall synthesis and cell expansion. Boron deficiency disrupts reproductive growth, shoot and root growth and pollen viability and hence influences seed set and yield. A lack of boron can result in deformed leaves and poor quality of harvest product



IODINE
Iodine has been found to be associated with enzyme sin plants. Research suggests that it is important for biological processes such as photosynthesis, energy metabolism and calcium-signaling. Iodine deficiency delays flowering and disrupts root, leaf and fruit development as well as plants' environmental and climatic stress defences.

SODIUM
Is essential for transporting CO_2 during photosynthesis for a limited number of plants. For other plant species, because it is chemically and structurally very similar to potassium, it can also fulfill many of the roles played by potassium, including metabolic ones.

COPPER
Copper plays a key role in nitrogen and hormone metabolism and is needed for many enzyme activities in plants, as well as for chlorophyll and seed production. Deficiencies can lead to crop failure and increased susceptibility to diseases such as ergot.

IRON
Iron is another essential component for creating chlorophyll and also serves as a catalyst for cell division which is central to plant growth. Many plants also use iron for their enzyme functions. A lack of iron results in yellowing leaves and poor fruit quality and quantity.

MANGANESE
Manganese plays a key role in a variety of plant functions including photosynthesis, enzyme activation, respiration and nitrogen assimilation. Deficiencies can cause weaker structural resistance against pathogens and less tolerance to drought and heat stress.

SILICON
Increases plant vigour and improves tolerance to abiotic stresses such as drought, salinity or heavy metals. It enhances plant cell wall's strength and structure, increasing resistance to plant diseases and insect pests. Good silicon nutrition stimulates photosynthesis and improves grain production.

MOLYBDENUM
Molybdenum is used by plants to reduce nitrates into usable forms and for biological nitrogen fixation by certain species. Insufficient molybdenum means some plants can't fix nitrogen from air to make proteins and can hinder normal plant growth.

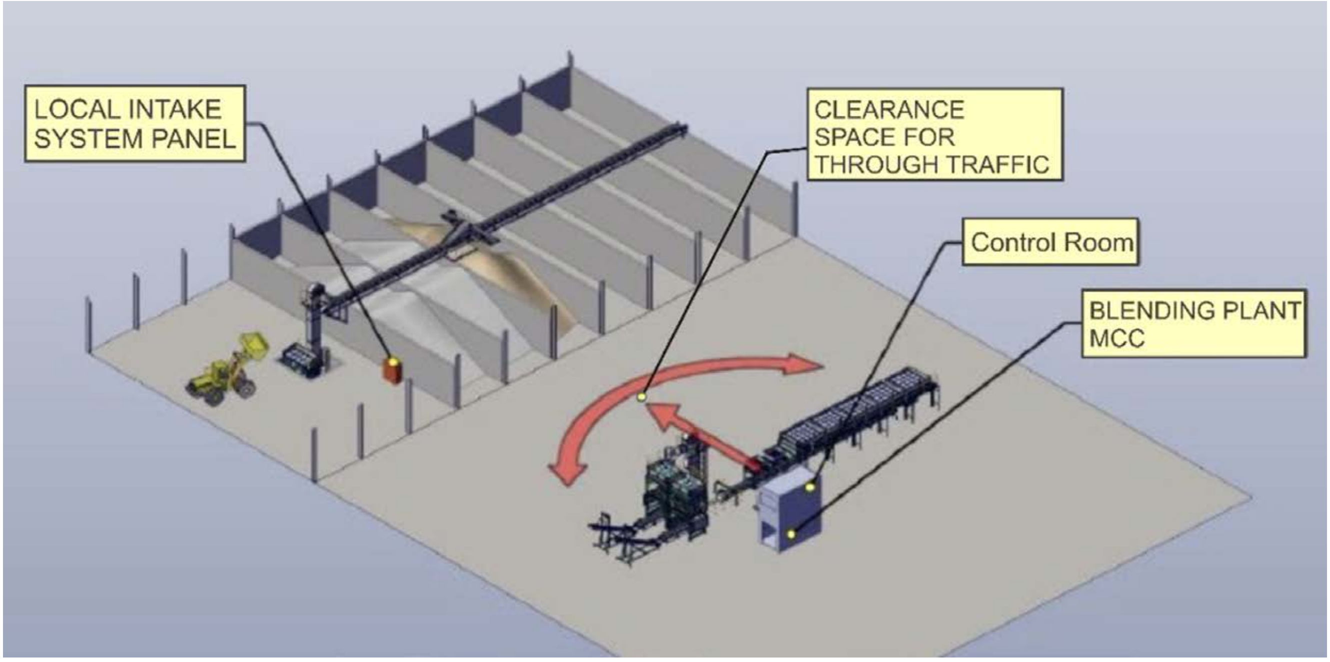
CHLORINE
Improves plant productivity, plays a role in photosynthesis and is needed for osmosis and iconic balance. It can help to minimize water loss during stressful dry periods and enhance disease resistance.

SELENIUM
Because selenium is chemically similar to sulphur, it is taken up inside plants via sulphur transporters inside the roots. Studies show that selenium improves plant growth and increases tolerance to biotic and abiotic diseases.

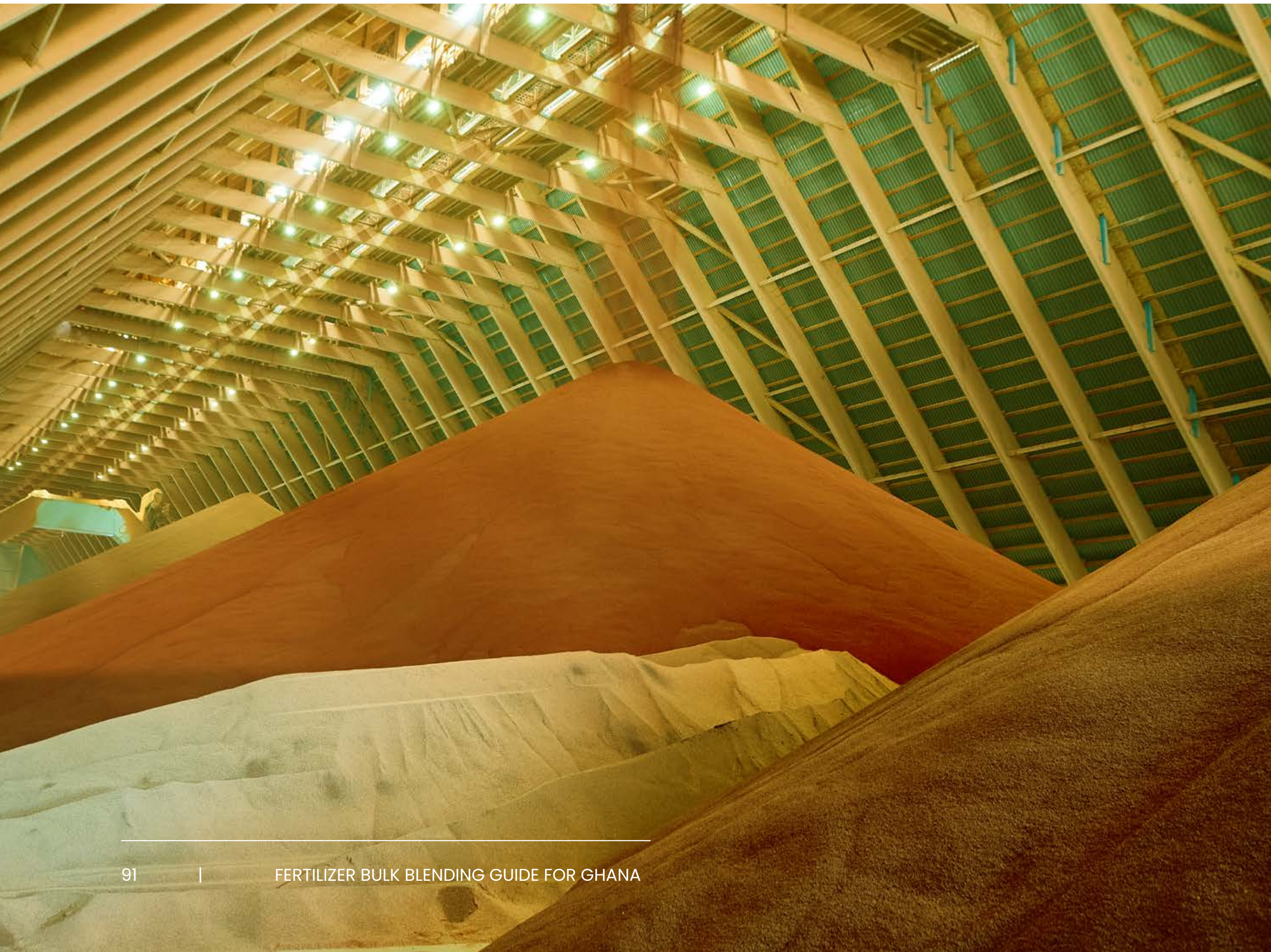
NICKEL
Nickel is important in plant seed germination, photosynthesis, enzyme functions and nitrogen metabolism.A deficiency affects plant growth, antioxidant systems and response to stress

ZINC
Participates in chlorophyll formation, is needed to activate many enzymes in plants and is needed for plant immune responses. As a result, it is important for increasing plant resistance to diseases and pests

I. Indicative Raw Material Receiving And Storage Layout



Source: Grant Ruwers, Lagos, 2019

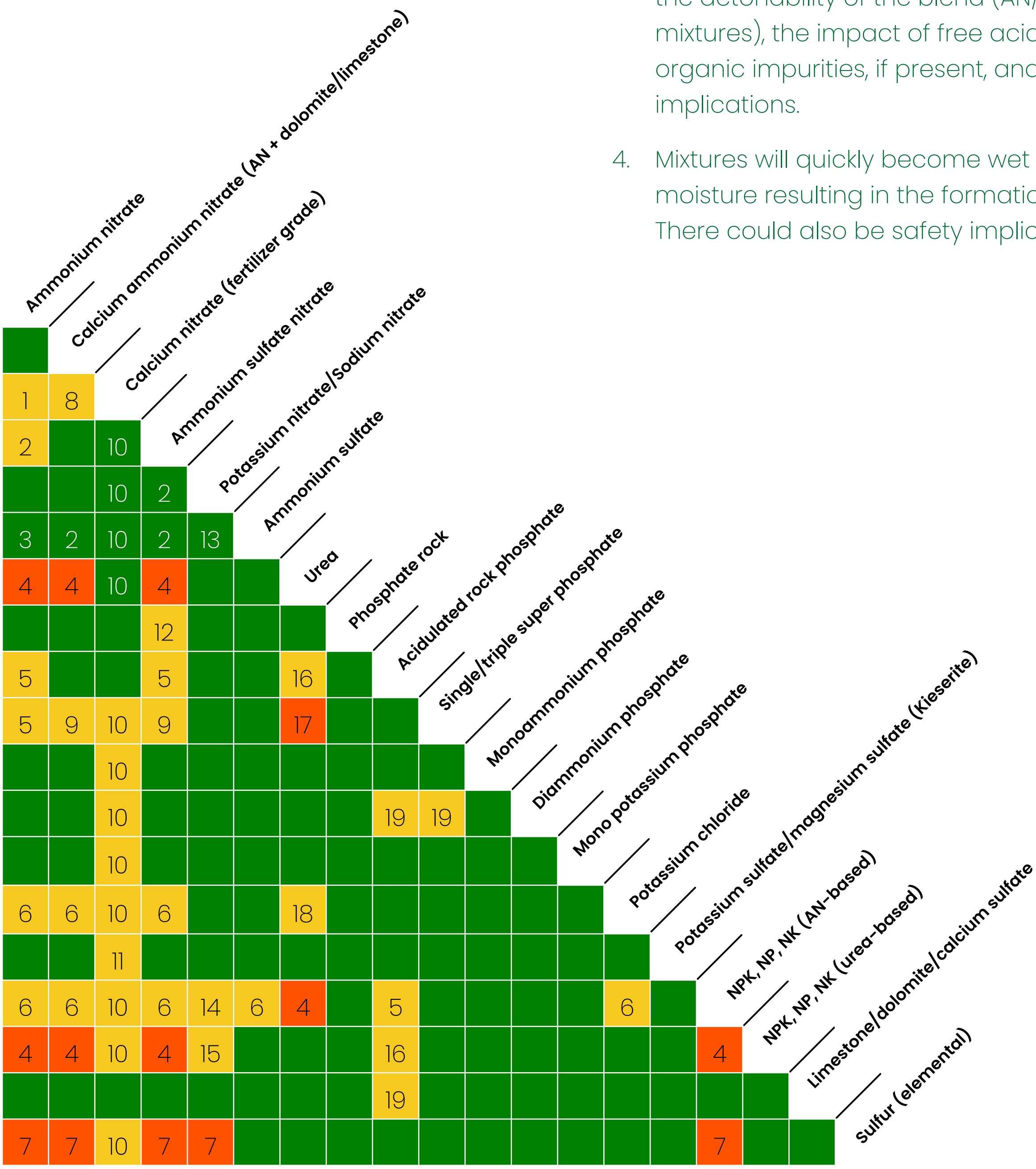


J. Fertilizer Compatibility Chart

Green: *Compatible*

Yellow: *Limited compatibility (chemically, physically, and/or safety-based)*

Red: *Incompatible (chemically, physically, and/or safety-based)*



Source: Handbook of Solid Fertilizer Blending, Code of Good Practice for Quality, 2016.

Compatible Materials

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 the detonability of the blend (AN/AS mixtures) and legislative implications.
3. Consider the safety implications regarding the detonability of the blend (AN/AS mixtures), the impact of free acid and organic impurities, if present, and legislative implications.
4. Mixtures will quickly become wet and absorb moisture resulting in the formation of a slurry. There could also be safety implications.

5. Any free acid present could cause very slow decomposition of AN, affecting, for example, packaging.
6. Consider the possibility of self-sustaining decomposition and the overall level of oil coating.
7. Sulphur is combustible and can react with nitrates, e.g. AN, KNO3, and NaNO3.
8. Due to the hygroscopic behaviour of both products, the type of stabilisation of the ammonium nitrate-based fertilizer could influence the storage properties.
9. Consider the moisture content of the SSP/TSP.
10. Consider the relative humidity during blending.
11. Risk of formation of gypsum.
12. No experience but this can be expected to be compatible. Confirm by test and/or analysis.
13. Consider impurities in AS and the drop in the critical relative humidity of the blend.
14. Consider the likely impact of additional nitrate.
15. Consider the possibility of ammonium phosphate/potassium nitrate reaction with urea and relative humidity during blending, to avoid caking.
16. If free acid is present, there is a possibility of hydrolysis of urea giving ammonia and carbon dioxide.
17. Formation of very sticky urea phosphate.
18. Potential caking problem due to moisture.
19. If free acid is present, consider the risk of a reaction, e.g. neutralisation with ammonia and acid attack with carbonates.

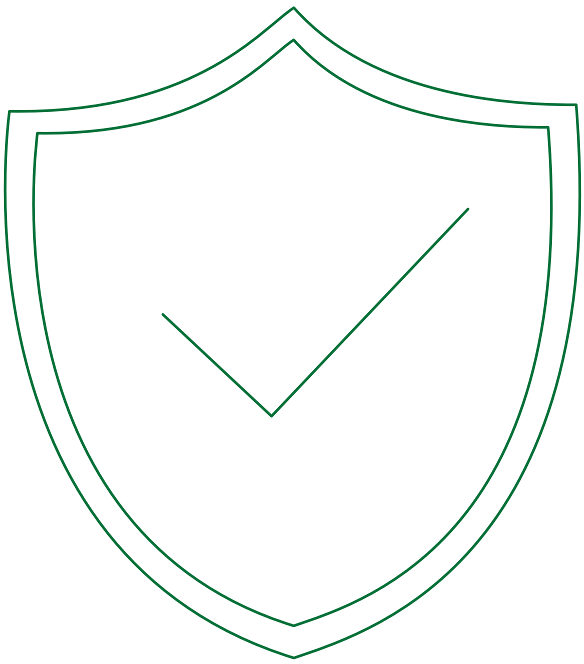
Not Compatible

- **NC1**. The mixture will quickly become wet and absorb moisture resulting in the formation of liquid or slurry. There could also be safety implications.
- **NC2**. Sulphur is combustible and can react with nitrates e.g. AN, KNO_3 and $NaNO_3$

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 diammonium 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.



K. Critical Relative Humidity of Fertilizers In Ghana

Critical relative humidities of pure salt and mixtures at 30˚C (86˚F)

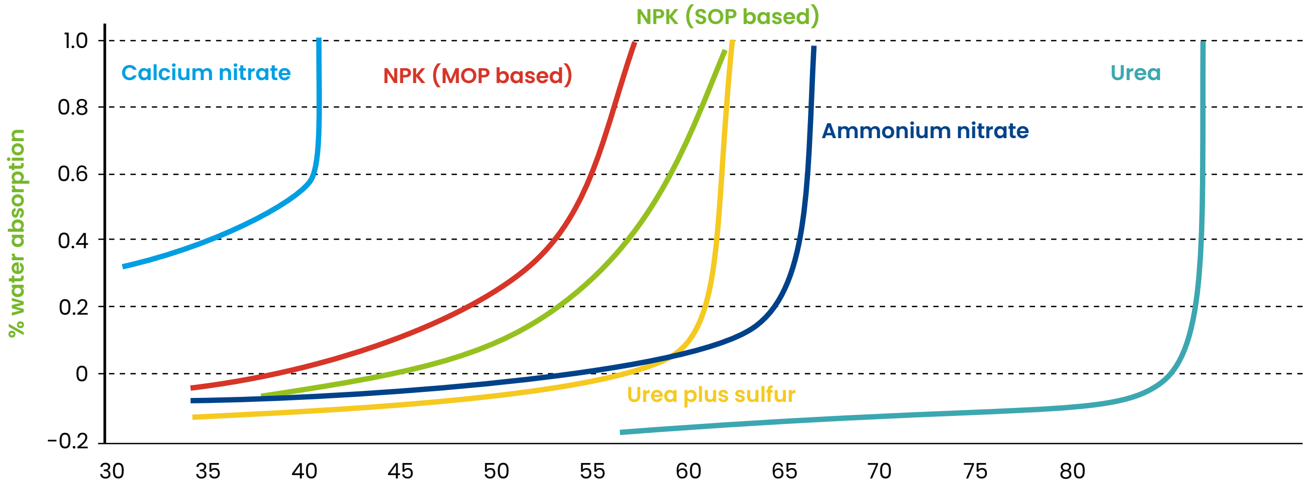
	Calcium nitrate	Ammonium nitrate	Sodium nitrate	Urea	Ammonium chloride	Ammonium sulfate	Diammonium phosphate	Potassium chloride	Potassium nitrate	Monoammonium phosphate	Monocalcium phosphate	Potassium sulfate
Calcium nitrate	46.7											
Ammonium nitrate	23.5	59.4										
Sodium nitrate	37.7	46.3	72.4									
Urea	–	18.1	45.6	72.5								
Ammonium chloride	–	51.4	51.9**	57.9	77.2							
Ammonium sulfate	–	62.3	–**	56.4	71.3	79.2						
Diammonium phosphate	–	59*	–	62*	–	72*	82.5					
Potassium chloride	<22	67.9**	66.9**	60.3	73.5	71.3**	70*	84				
Potassium nitrate	31.4	59.9	64.5	65.2	67.9	69.2	–	78.6	90.5			
Monoammonium phosphate	52.8**	58	63.8	65.2	–	75.8	78*	72.8**	59.8	91.6		
Monocalcium phosphate	46.2	52.8	68.1	65.1	73.9	87.7	78*	–**	87.8	88.8	93.6	
Potassium sulfate	76.1	69.2**	73.3**	71.5	71.3	81.4	77*	81	87.8	79	–**	96.3

** Approximate values obtained by Tennessee Valley Authority (TVA, Ref. 3). Other data are from literature.*

*** Unstable salt pair; the value given is for the stable pair.*

Critical Relative Humidity of Fertilizer at 25°C

Typically, a water absorption curve ascends slowly at low humidity (as illustrated), but at a certain humidity or humidity range it starts to increase steeply. This humidity is called the critical humidity of the fertilizer. The critical humidity goes down when the temperature increases.



Source: Yara, 2022

Example of caking in fertilizer, caused by ambient humidity in the storage area.

L. Jar Test Diagrams And Examples of Particle Size Distribution

Jar test Diagrams

DAP and coarse KCL: Segregation.

DAP and granular KCL: No Segregation.

Urea, DAP, and granular KCL: more compatible materials.

Source: CFI, 2013

M. How To Determine Sgn And UI Using The Graph Method

The size distribution is plotted on graph paper, percent cumulative (by mass) versus particle size. The normally smooth distribution curve is approximated by drawing straight line segments between adjacent data points, as shown in the graph below.

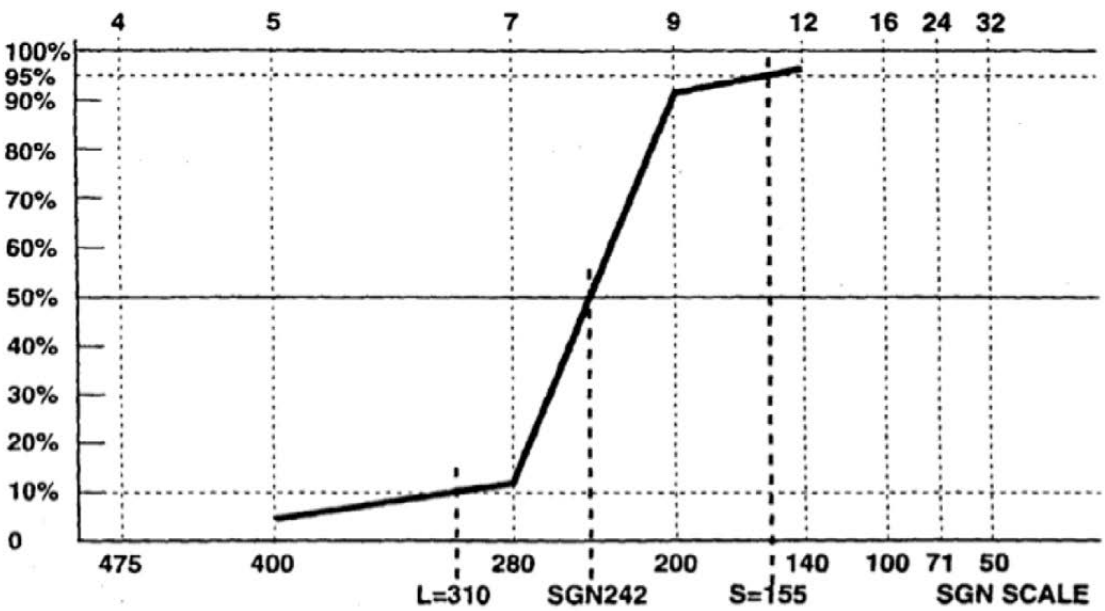
From the point where the cumulative data line crosses the 50% horizontal line, draw down a vertical line to the SGN scale for direct reading of the SGN value. SGN = 242 in this example.

From the point where the cumulative data line crosses the 95% horizontal line, draw down a vertical line to the SGN scale for direct reading of the small Particle Dimension, S = 155 in this example.

From the point where the cumulative data line crosses the 10% horizontal line, draw down a vertical line to the SGN scale for direct reading of the large Particle Dimension, L = 310 in this example.

(UI = (100 S)/L or, for example: (100 x 155)/310 = 50)

Tyler Mesh Number



Source: CFI, 2013

N. How To Determine Sgn And UI Using The Mathematical Method

The determination of SGN and UI would be simple if the screen tests showed exactly 10%, 50%, and 95% cumulatively retained on three different sieves. For example, 50% on the 2.36 mm sieve would immediately convert to SGN 236. Similarly, 10% on the 2.80 mm sieve and 95% on the 1.40 mm sieve would mean that UI = 50%, since UI = S/L x 100.

The screen test results, however, are rarely exactly 10%, 50%, or 95% on a particular sieve. To determine SGN, S and L, a mathematical method called linear interpolation must be used. The straight segments used in linear interpolation approximate the smooth S shape of the true size-distribution curve.

For example, if 46% is retained on the 2.80 mm sieve and 68% is retained on the 2.36 mm sieve, we know that SGN is between 280 and 236. The mathematically exact value can be calculated with the interpolation formula:

$$[a\,(CRA - k)]\,/\,(CRA - CRB) + b$$

Where k = 50 since we are calculating SGN
a = aperture difference = 280 - 236 = 44
b = aperture of the sieve retaining a proportion greater than k = 236
CRA = Cumulative Retained Above k = 68
CRB = Cumulative Retained Below k = 46
SGN = [44(68 - 50)]/ (68-46) + 236 = 272

The same interpolation formula is used for the determination of L and S, the dimensions of the "large" and the "small' particles, corresponding to the 10% and 95% levels of the cumulative distribution curve. The coefficient k is always 10 for L and 95 for S, while the other values depend on the screen test results. For example, 92% retained on the 1.70 mm sieve and 97% retained on the 1.40 mm sieve correspond to:

$$S = [30(97 - 95)]\,/\,(97 - 92) + 140 = 152$$

The best accuracy is obtained when consecutive standard sieves are used. Testing with every second or third sieve often affects the SGN estimate and always lowers the UI estimate. See Table H-1, for a list of standard screens.

O. The Sgn Scale And How To Determine Sgn Using The Sgn Scale Method

The Size Guide Number (SGN) Scale is an instrument designed for simple screen tests of fertilizer samples. It is a book-size acrylic box fitted with five sieves. It directly produces a size histogram of the sample tested, from which the SGN can be estimated.

The control sample of a fertilizer blend is truly representative only if the blending materials have been selected to minimise the risk of segregation in mixing and handling. Particle size is the most important factor in the selection of non-segregating materials. Particle size is commonly identified by the median dimension in millimetres times 100, or SGN. For example, if the screen test indicated that a sieve of 2.40 mm opening would retain exactly one-half of the sample, the average particle size would be 2.40 mm, or SGN 240.

Who can use the SGN Scale?

- The blender manager selects size-compatible materials.
- The blender operator prevents segregating blends.
- The control official identifies the increased risk of poor results.
- The basic manufacturing plants for process control.
- The marketing staff for promotional activities.

Procedure

- Transfer a representative sample of approximately 200 mL to the right end of the compartment of the SGN scale
- Close the SGN Scale and rotate it to bring the sample in the top position. Shake, long enough to finish sifting.
- Return the box to the horizontal position, to view the label in each compartment and to estimate the SGN. Remember that SGN is the scale value which divides the sample in two equal halves. As an example, if 50% of the sample is on the left of a line halfway between 200 and 280, this gives SGN 240. If 50% of the sample is on the left of a line eight tenths of the interval 200-280, this gives SGN 264.

P. Sampling And Testing Methods

Sampling Reports

In reference to ISO 5306:1983.
Fertilizers – Presentation of sampling reports, the sampling report shall include, in addition to the information specified by the various legal regulations: the date and location of sampling; the date of arrival of the delivery of fertilizer, if sampling has been carried out on the client's premises; the characteristics of the fertilizer sampled according to the information given on the bags or on the sale documents if it is in bulk, with the statement of the guaranteed elements; the nominal size of the delivery (number of bags, mass, etc.); the designation of the sampling unit taken; the number of increments taken (N); the number of aggregate samples prepared (N'); all observations noted on the packaging; a declaration stating that sampling has been carried out in accordance with this sampling procedure. In addition, the sampling report shall mention all operating details not covered in this International Standard, or which are optional, together with any events which may have influenced the results.

Sampling Methods

Refer to EN 1482-1:2007. Sampling and sampling preparation. Part 1.

Sampling Quantity

If a bag weighs less than 5 kg, it is considered a sub-sample. If the final quantity of the sample is not sufficient, the number of selected bags can be increased. A 50-kg bag should be divided to get an adequate representative sample. It is best to take samples while emptying the bag, though this may not always be possible.

For bagged products:

- Less than 5 bags require a sample taken from each bag.
- 4 to 11 bags of products require samples taken from 4 bags.
- 10 to 400 bags of products require samples taken from a whole number above the square root of the number of bags.
- More than 400 bags of products would require 20 bags of samples.

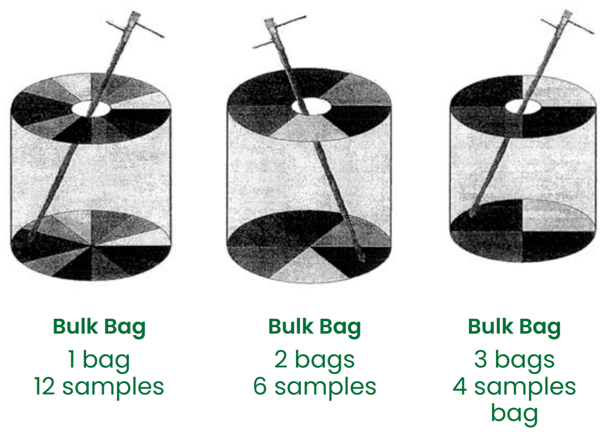
For product bays/bins:

- For product bays/bins, incremental samples are to be taken as listed below:
- Bay/bin sizes 25 tons or less require a minimum of 10 sampling units.
- Bay/bin sizes between 25 and 400 tons require sampling units of the nearest whole number above the square root of 4 times the number of tons present.
- Bay/bin sizes of more than 400 tons require 40 sampling units to be taken.

Figure 8. Bulk Bag Sampling

Source: International Fertilizer Association. IFA, 2017

Figure 9. Bulk Bag Sampling 2



Source: International Fertilizer Association. IFA, 2017

Sampling Bulk Bags (≥1 mt)

The minimum conditions to be satisfied in ensuring the quantity of sample collected for testing fairly represents the total quantity contained in the bag (≥1 mt) are:

1. Determine what the sample is required for.
2. Establish the characteristics of the material, e.g. its qualities, particle size and compatibility.
3. Insert a double tube trier from the centre of the open top through the bulk bag in a manner that collects samples from the entirety of the bag.
4. Angle the tube at about 30° towards the bottom outer end of the bag. Open the trier to enable the material to fill it. Close the trier and take it out of the bag.
5. Ensure the sample is of adequate volume or mass for the analysis
6. For a lot of 3 bulk bags or more, 4 samples of equal mass should be taken from each quadrant of the bag.
7. For only 2 bulk bags, divide the bag into 6 equal vertical segments and probe each part.
8. For only 1 bulk bag, divide the bag into 12 equal vertical segments and probe each part.

The results of several experiments carried out suggest that sampling results derived from both the techniques of stream cutting and sampling of bulk bags are identical.

However, for a more accurate method, collect samples while the material is in motion i.e. when either the ≤50 kg or the ≥1 mt are being filled. As per protocol, during sampling, the health and safety of the person collecting the samples should be taken into serious consideration.

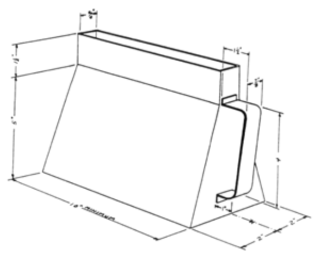
Sampling Equipment

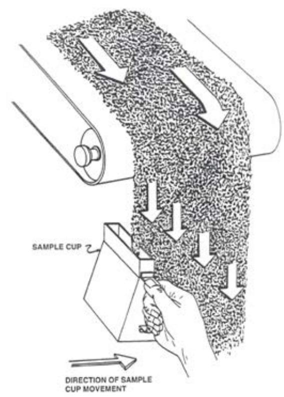
The double tube trier, also known as the spear, is recommended for probe sampling. But the trier's dimensions must be suitable to the properties of the sample quantity and the size of its particles must be a minimum of 3x the particle size.

Samples collected should be stored in airtight, moisture free and transparent containers to preserve the integrity of the samples. The success of the use of sampling equipment is reliant on the material flowing freely, thus, easy to penetrate without causing damage to the particles.

For materials that do not flow freely or that do not penetrate easily, other equipment, like a shovel or scoop, should be utilised to collect the samples.

Figure 11. Double Tube Trier in open and closed positions





Source: International Fertilizer Association. IFA, 2017

Figure 10. Example of a sampling cup and how it is used

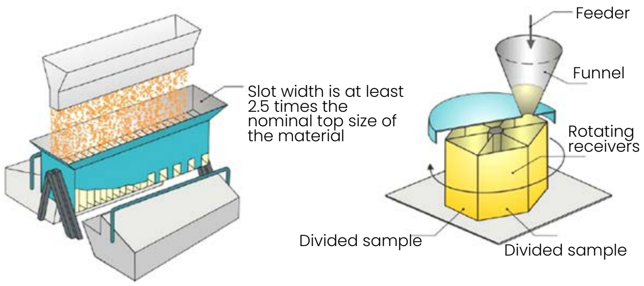
Source: Handbook of Solid Fertilizer Blending, Code of Good Practice for Quality, 20166

Sample Divider

When sieve analysis is to be carried out on blends being tested, rotary sample dividers are recommended. Riffle dividers are less appropriate for blended products but may be used for raw materials.

When carrying out chemical analysis, crushing the samples is recommended before the sample is finally reduced. Samples are not to be crushed for the measurement of physical properties.

Figure 12. Riffle Box and Rotary Sample Divider



Example of riffle box *Example of rotary sample divider*

Testing Methods

Chemical Analysis

National Standards, European Union (EC) Directives, European and International Standards, and the Association of Official and Analytical Chemists (AOAC) analysis methods are standard reference test methods for the most common chemical analysis used for fertilizer materials. Refer to Section 1.3 for ISO methods. Using these methods for routine process control and sampling is not essential; automated methods are often available. Although other methods can be explored, they must be benchmarked and evaluated against these recognized industry standards.

Physical Tests

The bodies mentioned above have existing guidelines on the test methods for numerous physical properties.

However, it is recommended that blenders pay attention to test sieving and bulk density. Some laboratories have accreditation for these special measurements. No standard methods are available for properties such as free dust and caking. For the sake of naturally occurring segregation, sampling is a fundamental step for physical testing.

Fundamentally, sampling is an important element for physical testing due to the occurrence of natural segregation. Another aspect to consider is the quantity needed for a final sample; it has been proven that this may be more than 5 kg for physical testing.

Test Method For Sieve Analysis

Principle

Use a mechanical sieving machine with one or more test sieves to dry sieve a sample fertilizer material.

Apparatus

- Weighing balance calibrated to weigh to the nearest 0.1 g.
- 200 mm diameter stainless steel woven wire test sieves with a lid and receiver for the sieves.
- A sieving machine, also known as a mechanical shaker. Should be able to apply horizontal and vertical motion to the material on the set of sieves.
- Stopwatch and a soft brush.

Procedure for testing

- In accordance with best practices, it is recommended to reduce the sample to approximately 250 g, most preferably ensuring the use of a rotary sample divider or a riffle divider.

- Collect seven sieves to secure the range of particle sizes expected and arrange them in ascending order of aperture size on top of the receiver.
- Check the weight of the test sample and round it up to the nearest 0.1g. Secure the sample with a lid and place it on the sieve.
- Put the set of sieves along with the sample on the shaker and shake for up to 10 minutes. From the top, separate the sieves from the nest and weigh the retained quantity left on each sieve including the receiver.
- Round off the derived weight to the nearest 0.1 g.
- Using the brush, clean the remaining particles in the nest. Add up what is left on the sieve and receiver and ensure it is within 2.5 g of the original sample mass.
- Express the mass of each leftover as a percentage of the original mass and plot a table showing the cumulative percentage passing each sieve.

According to the Handbook of Solid Fertilizer Blending, Code of Good Practice for Quality, 2016, the percentage of material leftover in the receiver and on each sieve is derived from the equation, Xn = (mn/mt) * 100, where mn is the mass on sieve n, mt is the total mass (m0 + m1 + ...), and Xn is the mass percentage retained in sieve n.

Also, the formula for the cumulative undersize is expressed as Cn = X0 + X1 + X2 + ... + Xn-1, where Cn is the cumulative percentage undersize for sieve n.

Test Method For Loose Bulk Density

Principle

Weighing a known volume of the fertilizer.

Apparatus

- A balance calibrated to weigh to the nearest 1g.
- A 60 mm diameter, 1 litre cylinder of known volume.
- A standard 25 mm diameter aperture funnel.

Procedure

1. Carefully place the sample unit of fertilizer in the funnel just as seen in the image of the equipment in Figure 13. Ensure that the aperture is properly closed.
2. Check the weight of the empty barrel and place it right beneath the funnel.
3. Release the fertilizer to flow gently into the barrel and close the funnel after the barrel is full. Remove excess fertilizer with a spatula then weigh the barrel and the content in it.
4. Calculate the weight of the content as (m in kg).

   The formula for calculating loose bulk density is represented as:

$$\rho = \frac{m}{V}, \text{ where } m = \text{mass and } V = \text{volume}$$

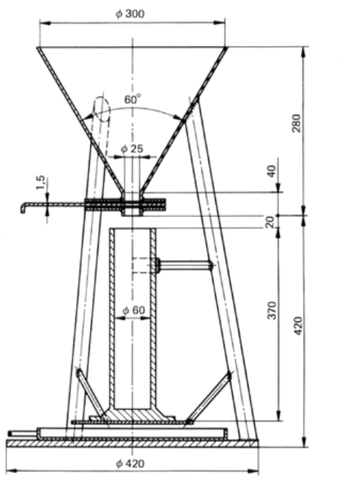


Figure 13. Loose density measuring equipment

Source: Handbook of Solid Fertilizer Blending, Code of Good Practice for Quality, 2016.

Test Method For Angle of Repose

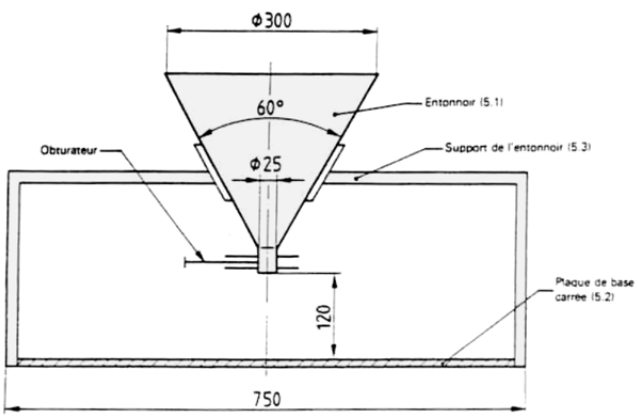
Principle

Measuring the diameter of a heap of known height and calculating the angle of the heap.

Apparatus

- Horizontal surface measuring 750 x 750 (mm) and four lines presenting an angle of 45˚ between and traced at the surface centre.
- A standard 25 mm diameter aperture funnel placed 120 mm above the surface.

Figure 14.Angle of repose measuring equipment



Source: Handbook of solid fertilizer blending, code of good practice for quality, 2016.

Procedure

A total of 5 kg of fertilizer is placed in the funnel with a closed aperture. Fertilizer is allowed to flow freely onto the surface from a heap by opening the aperture. The flow is stopped when the heap reaches the bottom of the funnel. The four diameters on the plate are measured, and the average diameter (d in mm) is derived. The value of the angle of repose is calculated using the following formula:

$$\alpha = \arctan\left(\frac{240}{\bar{d} - 25}\right)$$

Example

Examples of results of physical tests on fertilizers are given. The data set is realistic, but the physical properties will vary significantly for the same product contingent on its origin. The following results were obtained for three diverse fertilizers A, B and C using previously described measurement methods.

Example of data from the laboratory for physical testing of three fertilizers:

	FERTILIZER		
SIEVING TEST	**A**	**B**	**C**
< 1.00 mm	0.1 g	0.5 g	8.2 g
1.00 to 2.50 mm	1.2 g	9.3 g	35.6 g
2.50 to 2.80 mm	5.3 g	19.9 g	45.2 g
2.80 to 3.15 mm	36.7 g	68.1 g	51.9 g
3.15 to 3.55 mm	115.2 g	79.6 g	46.8 g
3.55 to 4.00 mm	67.7 g	51.2 g	35.3 g
4.00 to 5.00 mm	15.9 g	13.2 g	21.7 g
> 5.00 mm	2.1 g	2.1 g	5.2 g
Total	244.2 g	243.9 g	249.9 g
Loose bulk density			
Weight of 1 litre (V=0.001 m³)	1,000 kg	0.750 kg	0.950 kg
Angle of repose			
Average diameter base of the heap (d^)	400 mm	400 mm	325 mm

Determining the physical properties of these fertilizers is achievable by using the formula.

	FERTILIZER		
Sieving test	Weight (g)	Percentage (%)	Cumulative %
< 1.00	0.1	0.04	0.04
1.0 – 2.50	1.2	0.49	0.53
2.50 – 2.80	5.3	2.17	2.7
2.80 – 3.15	36.7	15.03	17.73
3.15 – 3.55	115.2	47.17	64.91
3.55 – 4.00	67.7	27.72	92.62
4.00 – 5.00	15.9	6.51	99.14
> 5.00	2.1	0.86	100,00
Total	244.2	–	–

	FERTILIZER		
Sieving test	**A**	**B**	**C**
d16	3.11 mm	2.85 mm	2.34 mm
d50	3.42 mm	3.27 mm	3.04 mm
d84	3.86 mm	3.79 mm	3.83 mm
GSI	10.96	14.42	24.55
Loose bulk density (ρ)	1,000 kg/m³	750 kg/m³	950 kg/m³
Angle of repose (α)	32.6°	32.6°	38.7°

Given the above test data, the mean particle size (d50) and the Granulometric Spread Index (GSI) can be determined. The d50 ranges between 3.15 mm and 3.55 mm, the d16 is slightly below 3.15 mm and the d84 ranges between 3.55 mm and 4.00 mm.

Therefore,

$$d_{16} = 2.80 + \frac{16 - 2.70}{17.73 - 2.70}(3.15 - 2.80) = 3.11 \text{ mm}$$

$$d_{50} = 3.15 + \frac{50 - 17.73}{64.91 - 17.73}(3.55 - 3.15) = 3.42 \text{ mm}$$

$$d_{84} = 3.55 + \frac{84 - 64.91}{92.63 - 64.91}(4.00 - 3.55) = 3.86 \text{ mm}$$

$$GSI = \frac{3.86 - 3.11}{2 \times 3.42} \times 100 = 10.96$$

In conclusion, we will find that:

- Fertilizer A has very low GSI because its particles are similar in size.
- Fertilizer C has high GSI because it contains more tiny particles.
- Fertilizer B possesses low bulk density.
- Fertilizer C has a high angle of repose because it contains more particles that are angular in nature.

NB: The above example is an excerpt from The Handbook of Solid Fertilizer Blending, Code of Good Practice for Quality, 2016.

Q. Indicative Checklist For Blending And Bagging Operations

1. Before the day of blending, check if the raw materials required to satisfy the nutrient guarantees are available.
2. Check if the formula grade is correct.
3. Check if all weighing scales are reset to "zero".
4. Load raw materials (macronutrients and micronutrients – if applicable), until bins are full.
5. Start the blending process.
6. Visually inspect the movement of materials from hoppers to the mixer:
7. Are there lumps?
8. Is there too much dust?
9. Is a bag connected to the fines discharge hopper?
10. Start the bagging process after the product hopper is full.
11. Start the bag stitching process.
12. Check bag weights manually at intervals.
13. Start the palletizing process.

R. Indicative Checklist For Plant Maintenance

1. Removing obstructions:

a) Remove the cover sheet.
b) Check the gate's full range of motion.
c) Turn on the isolator.
d) Power the plant back up.
e) Open manual shutoff valve.

2. Releasing jammed screw conveyor (if applicable):

a) Close the manual shutoff valve fully.
b) Switch off the plant.
c) Switch the plant to local mode.
d) Change motor drive direction and frequency to run the plant in reverse.
e) Run the screw repeatedly in reverse and forward to release the jam.
f) Open the manual shut-off valve.
g) Reset motor driver settings.

3. Purging products left in hoppers:

a) Switch the plant off, switch the plant to local mode and switch the direction and frequency of the motor drive to enable the belt to run backwards.
b) Place a purge collection bag at the tail of the conveyor and ensure someone is controlling the bag to avoid bag collapse and overfilling of purged product.
c) Start the conveyor and open the bin to be purged manually.
d) When done, return all motor settings to normal.

4. To purge products through the bagging machine:

a) Switch the bagging setting to manual.
b) Move the stitching conveyor to make space for bulk bags if a large amount of product is to be purged.
c) Start up the bagging equipment and open the bin to purge.
d) Repeat until purging is completed, remove the bulk bag and replace the stitching conveyor.

5. Cleaning motor fans:

a) Remove the fan cowl.
b) Blow out the fan.
c) Check for unobstructed movement of the fan.

S. Indicative Checklist For Plant Safety

1. Safety precautions and signs

a) The plant should have adequate access for installation, operations, and maintenance.
b) Safety harness should be worn when working at height on the plant.
c) Adopt the "look-before-you Leap" approach in the vicinity of the plant.
d) Install standard information, warning signs, and labels on and around the plant area.
e) Ensure the information and warning signs are not removed unnecessarily.
f) Do not reach into or over any part of the plant while it is running.
g) Follow proper "lock-out" procedures when cleaning, servicing, or maintaining the plant.

2. Inspection

a) Carry out an adequate visual inspection before starting the plant.
b) Look out for foreign objects or loosely hanging parts before running the plant.
c) Critically observe the plant for its mechanical, electrical and instrumentation readiness before operating it, e.g. look out for worn, touching, or rubbing mechanical parts, loose or hanging electrical wires, and error signs on the computer systems, display screen or PLC board.
d) Make sure the plant is ready for production by ascertaining that all the raw materials, material and labour resources, electrical supply, compressor, etc., are present.

3. Access

a) Cat ladders, step ladders, and access platforms should be provided alongside the plant and utilised, according to standard practice, for works at height.
b) Due to the corrosive nature of the product, these components for accessing heights can become rusted and their structural integrity lost. Therefore, care should be taken to maintain them regularly.
c) Lock-out/tag-out signs should be visibly installed and adhered to, especially during any kind of maintenance.
d) Work should be done from the platforms around the hoppers and not directly in or on them.
e) Only trained and authorised personnel should work in service hatches located on different parts and interconnection points of the plant.
f) Avoid the underside of the pulley guards on the conveyors because it is open.
g) Do not touch rollers and pulleys while the plant is powered up.
h) Only trained and authorised personnel should touch electrical and instrumentation panels, displays, and touchscreens.

4. Personal protective equipment (PPE)

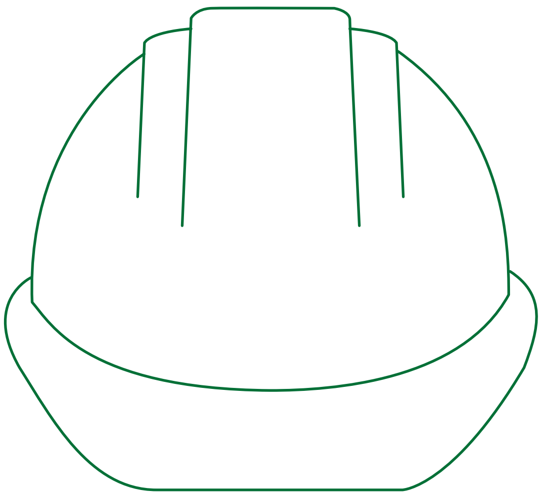
a) Hard hats should be worn to prevent head injury.
b) Dust masks or respirators should be worn to prevent dust inhalation and breathing difficulty.
c) High visibility clothing should be worn to prevent accidents due to moving vehicles.
d) Safety boots should be worn to prevent leg and foot injury.

5. Magnet

a) Install a permanent plate magnet over the under-bin conveyor to remove external metallic objects from the product.
b) Keep medical, electronic, and personal devices that can be affected by strong magnetic fields away from the plant to prevent malfunction or outright damage.

6. Fire Hazard

a) Ensure the entire production facility adheres to the local safety, health, environment, risk, and quality laws and regulations.
b) Conduct a Hazard Identification and Risk Assessment exercise before starting the plant and after any operational changes are made.
c) Adequate care should be taken to keep flammable materials and ignition sources away from the plant and fertilizer raw materials.
d) Dry CO_2 extinguishers should be installed in high-risk zones around the plant.



NOTES:

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