

Bone Phosphate Lime Sampling Method

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Abstract

Shipping primary products worldwide in considerably large quantities involves keeping track rigorously of the materials quality, especially when the product shipped is quantified in tons. Keeping that in mind, the team has to provide the customer few samples, which will be analyzed for quality, chemical and mineral composition, water concentration, and particle size.

The degree of homogeneity among phosphate lots is very small, meaning that we can find very dispersed quality proportions of the product throughout the lot. Accordingly, the sampling team must make sure to follow certain criteria to retrieve the sample. This paper aims at setting a correct sampling guideline for phosphate.

Keywords

Phosphate – Sampling – Gy’s Method – Representativeness – Homogenization – Particle size analysis – Conveyor

1. Gy’s Formula

Also known as the “Theory Of Sampling” (TOS) is a sampling method oriented for continuous random variables, i.e. infinite uncountable samples, established by Pierre Gy in mid-20th century. The scientist proposed an equation that can help engineers figure out many valuable data for their sampling experiments, most importantly M, the minimum sample weight for the population or S^2 the standard deviation.

In the context of my internship, I will need to propose an accurate and valuable sampling method, and compare it to the existing ones, either within the directorate of Casablanca’s harbor of OCP or other institutions. I heavily relied on Gy’s method of sampling as it is considered the most effective one.

The general formula used by Pierre Gy is:

$$\frac{W - M}{WM} = \frac{C(d_{\max})^3}{S^2}$$

Or for the cases where $W \gg M$:

$$M = \frac{C(d_{\max})^3}{S^2}$$

Considering the following parameters:

- M = Sample mass (g)
- W = Mass of the lot (population) (g)
- C or K = Sampling constant of phosphate (g/cm³)
- d_{MAX} = Maximum diameter of a unit (cm)
- S = Standard deviation that will be required to provide the highest level of essential certainty (Quality deviation) (Kawatra, 2009).

In phosphate sampling context, we will use this equation in order to determine the minimum sample weight needed M.

As phosphate is available under many different forms, I had to chose the most appropriate one for which I retrieved the chemical information that would be used in the formula above. When freshly extracted, phosphate is under the form of P₂O₅, which concentration in the lot is approximately 30%, until it is processed further to increase this percentage to around 70%. The chemical composition of phosphate becomes PO₄ under the name of BPL (Bone Phosphate Lime). Therefore, I chose to gather all my information on the BPL material, as it is the ground form of phosphate.

1.1 Calculating S

We want a phosphate assay to be accurate within ±1 % of phosphate (degree of confidence). If we divide this value by the mean probable assay value ...%, we get the standard deviation.

As phosphate is classified within five different quality ranges, we will need to calculate the following value for each by using the formula:

$$A = \frac{\text{Accuracy}}{\text{Assay Value}}$$

Then, we must find the corresponding probability value for the degree of confidence we are working with using the probability tables for Z-scores. As we are working with a degree of confidence of α=1% (the maximum value at which each quality will be unique from the other as there are minimum 2% difference between them), we must look for the Z-score of the probability the confidence interval minus half of the degree of confidence = CI - $\frac{\alpha}{2}$ = 99.5% = 0.995.

The resulting Z score is 2.807034. Relating the values of A and Z we can get S by:

$$S = \frac{A}{Z}$$

Quality K02:	Assay value: 65 Accuracy: ± 1 % A ₀₂ =0,0153846 S ₀₂ = 0,005481 S ₀₂ ² =0,00003	Quality K20:	Assay value: 72 Accuracy: ± 1 % A ₂₀ =0,0138889 S ₂₀ = 0,004948 S ₂₀ ² =0,000024
Quality K09:	Assay value: 68 Accuracy: ± 1 % A ₀₉ =0,0147059 S ₀₉ = 0,005239 S ₀₉ ² =0,000027		
Quality K10:	Assay value: 70 Accuracy: ± 1 % A ₁₀ =0,0142857 S ₁₀ = 0,005089 S ₁₀ ² =0,000026		
Quality K12:	Assay value: 70 Accuracy: ± 1 % A ₁₂ =0,0142857		

1.2 Calculating C

The sampling constant can be determined using the following formula:

$$C = f g l m$$

Considering the following parameters:

- “f = Shape factor = 0.5
- g = Size distribution factor = 0.25
- l = Liberation factor
- m = Composition factor” (Kawatra, 2009).

The shape factor f, ranged from 0 to 1, quantifies the extent at which the particles approach a squared pattern. In our case, the particles have a normal shape. Therefore, f is 0.5.

The size distribution factor g is a parameter ranged from 0 to 1 that quantifies the difference in particle sizes throughout the lot. Here, we set it to be 0.25 because the extreme sizes are proportionally related. The smallest fines are more than 4 times smaller than the biggest particles.

The corrected version of Gy’s formula involves a different expression for the liberation factor l. The originally proposed formula inquires that $l = \sqrt{\frac{L}{d}}$ with:

L = d_L the liberation size which is the size of liberated particles which is “the size to which an ore must be crushed or ground to produce separate particles of either value mineral or gangue that can be removed from the ore” (Mills). It amounts to the value of 60 microns = 0.006 cm.

d = d_N the nominal particle size or nominal maximum aggregate size (i.e. diameter of the biggest particle) = 2000 microns (according to the particle size distribution results cited later in this report) = 2 mm

Thus, following the formula: $l = \sqrt{\frac{L}{d}}$ the value obtained is $l = 0,1732$.

The right approach to define the liberation factor is to set its formula to be $l = \left(\frac{L}{d}\right)^A$ with **A** or **(3-a)** having a value between 0 and 1 being “an additional parameter of the model which can be adjusted based on experimental results” (Gy & François-Bongarçon, 2002).

One could wonder why such approximation is given to the public, but actually, Pierre Gy proposed this formula to encourage other scientists to perform further experimentations as to define the value of the exponent.

I will use the square root version of the formula, as I don’t have enough resources to perform the required experimentations to compute A.

1.3 Calculating m

The composition factor can be computed according to this equation:

$$m = \frac{1 - a}{a} [(1 - a) r + at]$$

Considering the following parameters:

r = density of the mineral $PO^4 = 961 \text{ kg/m}^3$ then $SG = 0.961$

t = density of the remainder of the material, which I personally calculated using an apparatus composed of a calibrated 1-L volume cylinder and a weighing machine.

$t_{02} = 1.533 \text{ kg/L} = 1533 \text{ kg/m}^3$ $SG = 1.533$

$t_{12} = 1.581 \text{ kg/L} = 1581 \text{ kg/m}^3$ $SG = 1.581$

$t_{09} = 1.542 \text{ kg/L} = 1542 \text{ kg/m}^3$ $SG = 1.542$

$t_{20} = 1.476 \text{ kg/L} = 1476 \text{ kg/m}^3$ $SG = 1.476$

$t_{10} = 1.558 \text{ kg/L} = 1558 \text{ kg/m}^3$ $SG = 1.558$

We can also deduce the specific gravities:

$$\begin{aligned} SG_{02} &= 1.533 & SG_{12} &= 1.581 \\ SG_{09} &= 1.542 & SG_{20} &= 1.476 \\ SG_{10} &= 1.558 \end{aligned}$$

a = fraction of phosphate in the composition (assay value)

$$\begin{aligned} a_{02} &= 0.2975 & a_{12} &= 0.3204 \\ a_{09} &= 0.3112 & a_{20} &= 0.3295 \\ a_{10} &= 0.3204 \end{aligned}$$

Now that we gathered all the required parameters for m , we can find:

$$\begin{aligned} m_{02} &= 2.671 & m_{12} &= 2.834 \\ m_{09} &= 2.527 & m_{20} &= 2.30 \\ m_{10} &= 2.444 \end{aligned}$$

1.4 Calculating d

At this stage, the only unknown parameter we are left with is the maximum diameter of a unit d_{max} . I asked for the particle size diameter analysis from the OCP of Khouribga. I received later on an excel sheet containing some data which I transferred into a graph. I repeated the operation for each quality and all the sketches obtained were approximately the same. Here is for instance the graph I obtained for the quality K02:

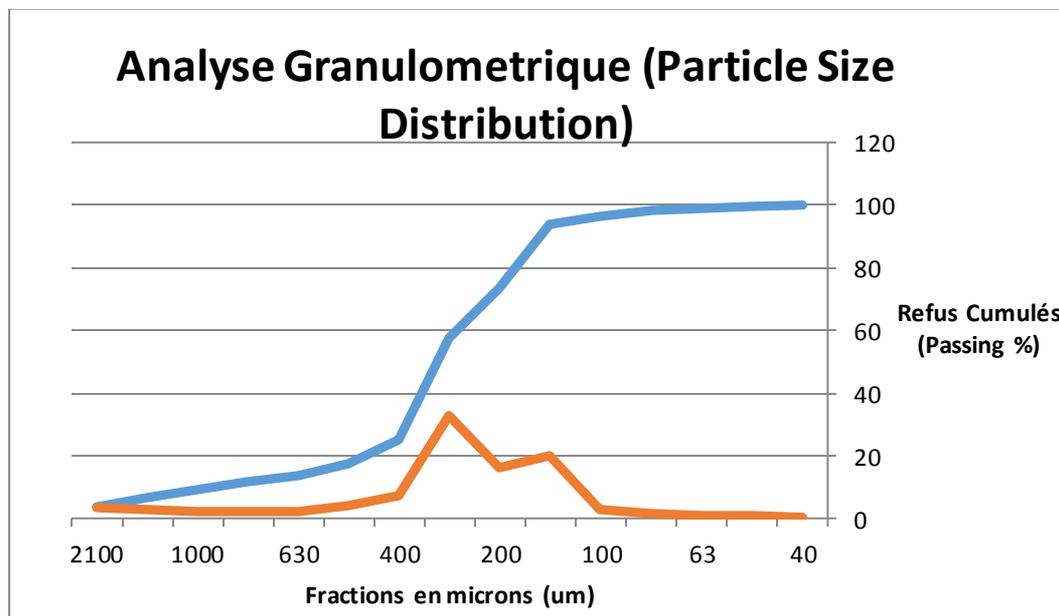


Figure 1. Graph of Particle Size Distribution Analysis for BPL

The red plot represents the non-cumulative passing %. The data illustrated is collected using an experiment consisting of a stack of sieves, which will separate the different-sizes particles of the material. Once we pour our sample in the stack, the sieves are placed in a machine that will vibrate for a while so that the particles go and scatter through the many little apertures located in each sieve. Once the vibratory step complete, we must

retrieve the percentages contained in each sieve, record its aperture size and its weight %. The obtained data are as I got from the laboratory. Thereafter, the maximum particle size is $d_{\max} = 2000$ microns = **2 mm**.

1.5 Results

Now that all the parameters are computed, we can calculate the minimum primary sample masses required for each quality, recalling the formula used:

$$M = \frac{f * g * l * m * (d_{\max})^3}{S^2}$$

$M_{02} = 15.42$ kg

$M_{09} = 16.21$ kg

$M_{10} = 16.26$ kg

$M_{12} = 18.86$ kg

$M_{20} = 16.59$ kg

Therefore, the minimum sample mass required would be 19kg.

2. Recommendations

My researches led me to the conclusion that the yield of a manual system is almost the same as the automatic one. However, the system used needs some few modifications in order to improve its efficiency.

In my opinion, modifications have to be done in the process of sampling, and not in the preparation process (homogenization and distribution). In fact, the “Riffle Splitter” is the second best tool used for the division of products, as it has a 1.01 standard deviation score, behind the “Sole Distributor” that has a value of 0.125.

The concepts that are normally recommended for the automatic sampling might serve as a template that will guide us to improve the present system. We can count among those principles:

- 1- the seizure must be made on the entire width of the conveyor (end to end).
- 2- the speed of the seizure must be constant in the entire crossing process, in order to be sure to have the same quantity of products in each position of the flux.
- 3- the sampled current flow has to be in a free fall; thus, it is best to make the seizure between the conveyor and the weighting machine in the load time.

Here is an example that respects those three principles:

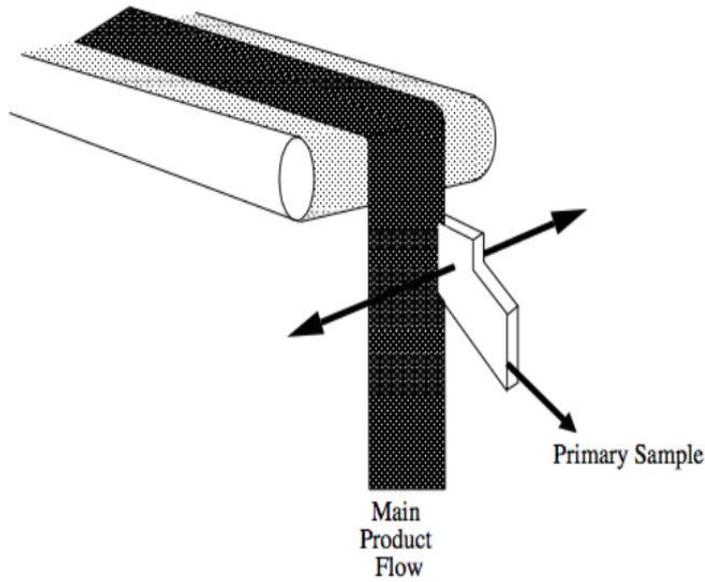


Figure 2. Linear traversing cutter

I suggest the use of this tool:

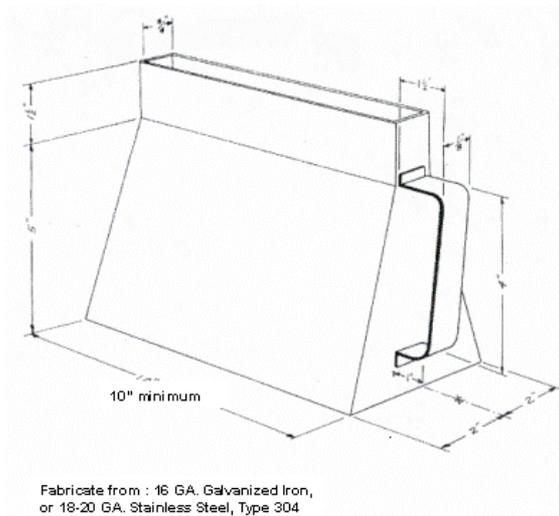


Figure 3: The Stream Sampling Cup (Government of Canada, 1997)

It is a cup specially made for the sampling flow, called “The Stream sampling Cup”. Its dimensions are as follows:

- H = 5”
- L = 10”
- l = 2”

Its volume will be: $100\text{in}^3 = 1,63871 \text{ L}$.
 This tool will allow us to seize the samples manually, with the possibility to have the cited principles applied, as it is shown in the side diagram.

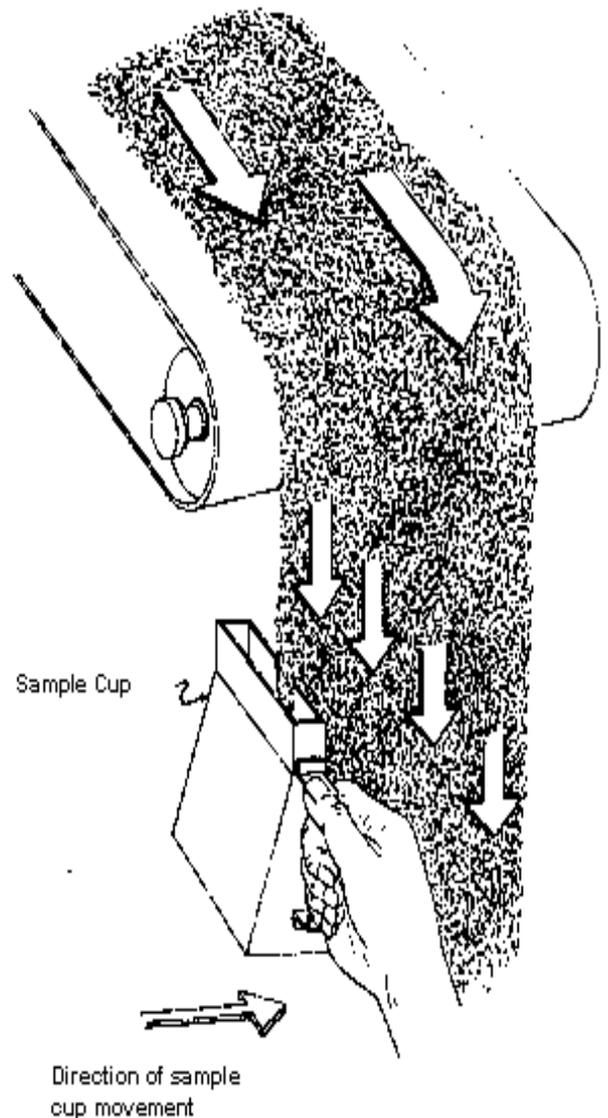


Figure 4: Linear traversing cutter (Government of Canada, 1997)

For security matters, we will have to use static port when the conveyor is running at full speed. In order to do that, we will use the Missouri "D" tool, which is a "Powder Sampler".

Its dimensions are as follows:

H = 1244,6 mm

ID (inner diameter) = 25,4 mm

The result of the volume capacity will be: $630648 \text{ mm}^3 = 0,630648 \text{ L}$.

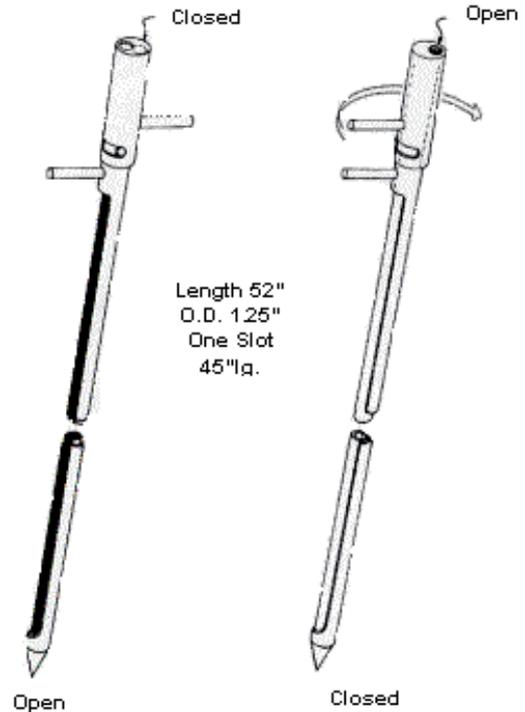


Figure 16: Missouri "D" Tube (Government of Canada, 1997)

The dimensions of the shovel provided within the OCP port office sampling station are:

H = 10 cm

L = 14 cm

l = 10 cm

As a result, we will have a capacity of $1400 \text{ cm}^3 = 1,4 \text{ L}$.

In order to have the same amount of the harvested products, the numbers of crosses made by the tool is:

- Missouri « D » Tube : 2,4 crosses
- Stream Sampling Cup : 1 cross

To sum up, an ameliorated sampling system will allow the company to reduce the risk of producing defected products, which means reducing the costs. Thus, it is recommended to apply the stated principles in order to diminish the risk. The solutions that I proposed are related to the sampling process, and imply the purchase of two seizure tools at a reasonable price.

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Biography

Wiam Aissaoui is an engineering student majoring in Engineering and Management Science at Al Akhawayn University of Ifrane, where she could take multiple subjects courses including physics, mathematics, materials science, thermodynamics, and more. She accomplished her internship requirement within the OCP group at Casablanca. This is her first contribution as conference paper. She did multiple summer jobs, noticeably within call centers or event planning agencies.