Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 13 (2017) 1135–1142

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra), Spain

Improvement of the Quality Control Plan in the reception of waste glass. Application in Verallia

J. Asín[a,*], M. Ávila-de la Torre[b], L. Berges-Muro[c], B. Sánchez-Valverde[a]

[a]*Statistical Methods Department, Engineering School,Zaragoza University, C/ Maria de Luna, 3, Zaragoza 50018, Spain*
[b]*Verallia Spain SA, Crta. Valencia, Zaragoza 50019, Spain*
[c] *Design and Manufacturing Engineering Department. Engineering School,Zaragoza University, C/ Maria de Luna, 3, Zaragoza 50018, Spain*

Abstract

The objective of the work is the improvement of the current Quality Control Plan in the reception of recycling material (cullet) in a glass factory, to check the conditions of the requirement specifications and, in particular, to reduce the presence of critical contaminants (ceramics, stone, porcelain,…) in the input material

Keywords: Quality control; recycling waste glass; statistical sampling; batch inspection

1. Introduction

Nowadays, cullet is the most important raw material in glass packaging industry. Its utilization represents, In terms of fossil-energy, a decrease of 3% for each 10% of cullet in substitution of natural raw materials, a decrease of urban wastes, water consumption, natural raw materials extraction, and a reduction of greenhouse gasses generation [6]. The only limitations for its use are the colour of glass produced, and cullet quality as input in term of contaminants: refractory materials, heavy metals, aluminum, etc. A very important part of material for a glass factory must be obtained from recycling material [1, 3, 9]. Verallia is the third largest producer of glass packaging for food and beverages, and it produces more than 25 billion bottles and glass jars annually for over 10,000 customers based in 46 countries around the world. Verallia leads the sector in Spain, with five production plants.

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: jasin@unizar.es

2351-9789
10.1016/j.promfg.2017.09.175

Since 1997, the management of cullet in Spain is governed by the law "11/1997, 24 Abril, de Envases y Residuos de Envases". Verallia, as manufacturer of glass packaging's, is obliged to consume cullet in its process. Now, around the 50% of raw material used in the glass factory of Verallia sited in Zaragoza (Spain) comes from recycled material. Several suppliers provide this type of material with a provision system similar to just-in-time. When the material is accepted in the factory, it is incorporated into the silo. Some problems were been detected in the current Control Plan in reception.

Then the objective of the work is the improvement of the current Quality Control Plan in the reception of recycling material (cullet) in the glass factory [8]. The plan must include the checking of conditions for the requirement specifications and, in particular, to reduce the presence of critical contaminants (ceramics, stone, porcelain,…) in the input material.

The objective is to establish a modification of the cullet control plan to which the suppliers are checked so that, on the one hand, we can work with batches in such a way as to ensure an adequate acceptable quality limit (AQL) and that, in addition, the supplier has the certainty that if the cullet verifies the quality criteria set, the probability that the product is accepted is very high. At this point, the standard UNE-ISO 2859-1 [4, 5] has been adapted to the cullet control to establish a sampling procedure for inspection by attributes, based on batches of homogeneous composition according to the supplier. In addition, this plan should include a sampling system that is actually representative of the batch quality and that sets a suitable sample size so that the fundamental measurement error (standard deviation of the measurement error) is always controlled.

The following section is devoted to analyze the database of control system of the previous years, and also some results are advanced from a pilot control plan. The proposal of a new Quality Contol Plan is presented in section 3, including the definition of batch, the description of sampling methodology to guarantee that sample is representative, according to verify bulk products, as cullet. Results after the implementation of the new plan are presented in the section 4 and, finally, section 5 summarizes conclusions and some open questions for future works.

2. Historical database and preliminary experiments

The initial phase of the project was an analysis of historical records of the previous control system. This procedure only took a sample of 20 kg for every truck up the surface of the dump. Some problems linked with selection method of samples were identified. Also, a rigorous inspection of trucks showed that the current control did not identify serious problems of presence of ceramics and stones in non-sampled load areas.

The control plan includes specifications to be signed by the suppliers of cullet, that document is SR.W.X.CC.200 / B in the company's quality plan. In summary, an exclusion list of any material other than container glass which may affect the quality of the glass produced, either infusible or because it affects the colour and / or oxidation state of the glass. The concentration limits of impurities appear in Table 1. The most critical criterion refers to infusible material, denoted KSP, that includes ceramics, stone or porcelain, since their presence causes problems in the furnace, increases the energy consumption and finally diminishes the quality of the product. An indirect evidence of infusible materials in the cullet is the percentage of mass associated to particles of diameter less than 5 mm, fine particles.

Table1. Limits for criteria considered in the reception of recycled glass.

Criteria	Maximum limit
Infusible contaminants, ceramics, stone, porcelain,… (KSP)	50 gr/Tm
Magnetic metals	0 gr/Tm
Light non magnetic metals	10 gr/Tm
Heavy non magnetic metals	35 gr/Tm
Organic matter	5000 gr/Tm
Particle with diameter < 5mm (fine particles)	5%

A minimum number of storage days must be verified by the supplier (15 days) to reduce the effects of organic matter. A deviation is usually tolerable provided that there is no sudden change in the storage time of the cullet, i.e. it should not be mixed cullet with 1 month of storage with cullet recently produced. This situation could provoke a strong variation of Redox that can lead to a crisis of refined and infused.

The internal records of the previous control on reception were analysed, with data from January 2015 to June 2016, see Fig. 1. Only 55 trucks of 2009 trucks were rejected, that is a rejection ratio of 2.7%. None was rejected for exceeding the limits in fine particles or in organic matter. 52 trucks were rejected by KSP and another 3 by exceeding the limits in non-magnetic metals.

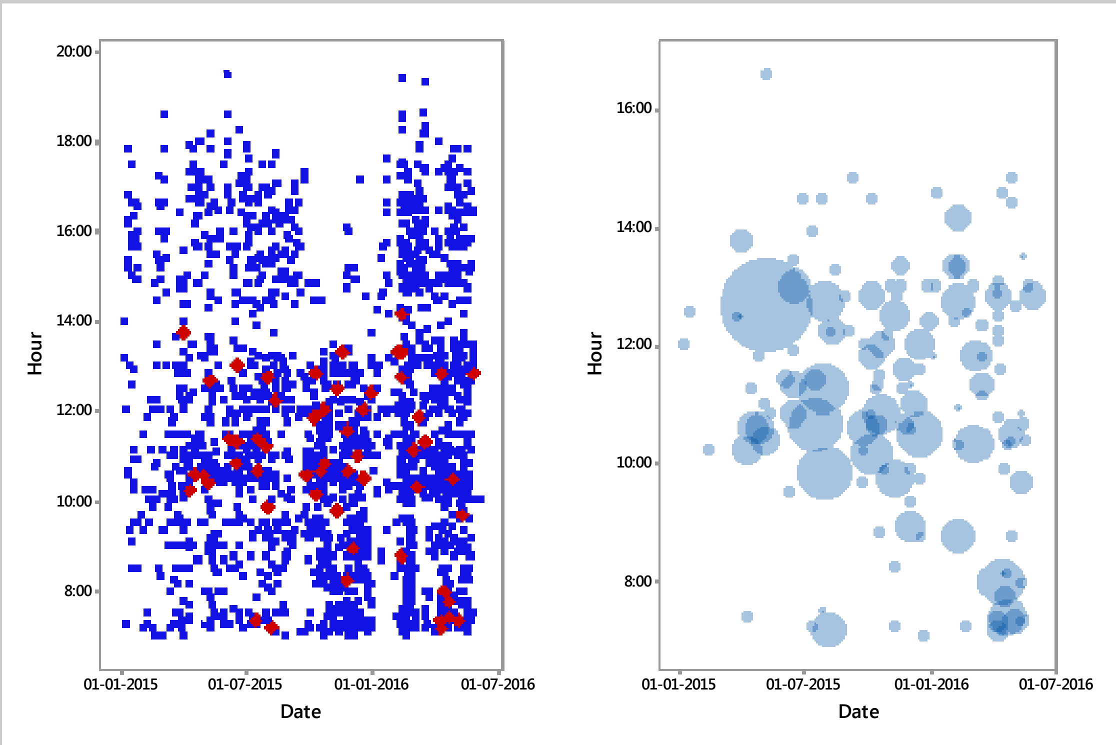

Fig. 1. Data base of previous Control Plan. (a) Date and hour of truck control with red symbols for rejected ones; (b) Bubble graph with radio defined by non zero KSP measures.

A data sampling method was designed through rigorous inspection of 3 trucks in a pilot experiment, conducted in July 2016. Those trucks are unloaded in the "truck hopper 3" to climb to the tower of cullet by the belt S21. During the unloading, five 15 kg sub-samples were collected from each truck, at different times of the unloading to try to avoid segregation through stratified sampling, and using a shovel designed to take pieces of cullet in all dimensions. With a temporary separation of about 6 min between each sub-sample in the discharge, a sample as representative as possible was obtained.

The results showed that the previous control did not identify serious problems of presence of infusible material in non-sampled parts of the dump truck. In the usual controls, no quantity of impurities is observed in any of the trucks and reduced amounts of fine particles were recorded. Thus, the previous control procedure came in acceptance.

As result of rigorous inspection, the average of percentage of fine particles in the 3 trucks is over the specification limits, see Table 2 and Fig. 2 left. The 95% tolerance intervals show that the results are far from reaching the control specification. The results show that, unlike the previous control, in almost all the sub-samples appear KSP, Fig. 2 right, in particular in the truck 3, KSP appear in all the sub-samples. The following fact appeared in the analysis: in several of the sub-samples where the percentage of fine material is high, the KSP measure is also high. It coincides with the logic that machines in small sizes close to 10 mm have worse efficiency to clean the KSP. In addition, the pieces of KSP were mostly of size close to 10 mm.

Table 2. Results *of pilot experiment.*

Criteria	Truck 1	Truck 2	Truck 3	Mean	Mean of sd
KSP <50 gr/Tm	20,3	31,0	59,8	37,0	32,6
Light non magnetic material < 10 gr/Tm	10,7	0,3	0,3	3,7	8,4
Heavy non magnetic material < 35 gr/Tm	0,0	0,0	0,0	0,0	0,0
Fine particles <5%	9,4%	10,6%	9,5%	9,8%	2%

At least, if the acceptation/rejection rule would be applied to results of rigorous inspection, then the batch would be rejected by fine particles, since all the trucks have been rejected. But the batch would not have been rejected by the KSP criterion since only a defective truck was detected. This fact implies that it is possible to consider different definitions of batch rejection according to the criteria control.

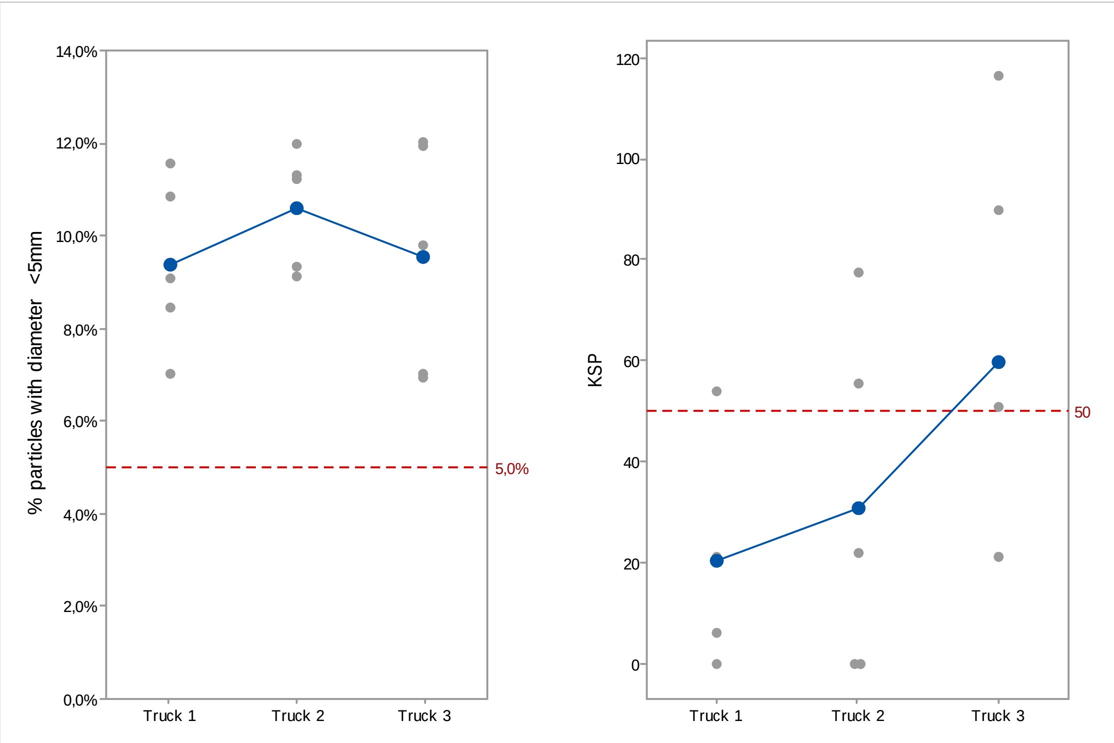

Fig. 2. (a) Percentage of fine material obtained in the pilot experiment. Grey points indicates the value measured in each sub-sample, blue points indicates the average value; (b) Percentage of KSP obtained in the pilot experiment.

3. Experimental procedure

The definition of batches (groups of transport units, i. e. dump trucks) is established to ensure an adequate Acceptable Quality Limit (AQL) and that, in addition, the supplier is guaranteed that if its waste glass verifies the quality limits, then the probability that the product will be accepted is high.

The UNE-ISO 2859-1 standard is used, which establishes a sampling procedure for inspection by attributes [7].

The material is processed continuously and this causes some difficulty in establishing a representative sampling. The plan includes the definition of a sampling system.

First, a random selection of trucks in a batch is made. Second, the extracted quantity of waste has been determined so that the fundamental measurement error, defined as the standard deviation of the measurement error, is limited. The theory and approximations of Pierre Gy [2] about the error characteristics in a bulk product sampling is considered [10, 11]. Third, the mechanical elements for the capture procedure have also been designed for this improvement.

3.1 Random selection of trucks

The batch size is defined according to the supplier. It could be the weekly order of cullet, but usually, and taking into account its production system, the practical definition would be associated to the size of the daily production. In that case, the supplier must ensure that the cullet corresponds to a production of a certain day. To do this, the supplier must have a separate storage with that cullet production of one day. Alternatively, the batch should be defined as the total production that corresponds to a separate container.

The usual batch size will be 75 Tm, that is, 3 dump trucks (in our case, the element that describes the standard is the truck).

The ISO-2859-1 requires as input data the batch size and the inspection level selected by the receiver. The rule recommends starting with general level II. From these requirements a letter is established that defines the control plan. For control plan in Verallia, the letter code will be the A for general level II. Once the inspection level is established, the procedure defines, first, the number of trucks to inspect the total of the batch and, second, it defines the acceptance/rejection rule for a defined AQL, i.e. the number of them that have not passed the control that is limit for the rule.

In our case, our code letter has been A, and it will continue to be A as long as the daily number of trucks does not exceed 8. In that case, we must inspect 2 trucks. The AQL will be 10%, that is, we would admit 1 of every 10 elements of the lot with some of its parameters to be controlled outside specifications. Then, if one of the two trucks inspected was outside, the whole batch would be admitted. Otherwise, the batch would be rejected.

The ISO standard describes situations for using a more or less rigorous sampling scheme depending on the provider's quality record. The level of control initially established is that of normal inspection, however, when detecting a problem sustained over time, one should move to the more demanding general level III.

The sampling must be random, which can give the situation of rejecting a lot of material that has entered a silo consumption. In this case, we propose to create a system of penalties to the supplier that obliges them to assume at least part of the cost of the quality that they generate. For example, they are charged an equivalent of the cost of transportation of the return of the batch.

3.2 Determination of sample size

The proposal is based on obtaining a representative sample of a bulk material in an item, lot, etc. And there by minimize the total sampling error. The expression developed by Gy allows us to define the sample size to be inspected so that the variance of the fundamental sampling error (which is part of the total sampling error) has a known and controlled value.

Starting from this last point, the fundamental error (*FE*) of the sampling is understood by the relative bias, i.e. the difference that exists between the value of a parameter estimated by the analysis of a representative sample (*CS*) and the true value of that parameter (*CL*) in the material set.

$$FE = \frac{CS - CL}{CL} \tag{1}$$

The variance of this fundamental error for a bulk material is given by the following expression:

$$Var(FE) = S^2 \approx K\, d95^2 \left(\frac{1}{M_S} - \frac{1}{M_L}\right) \tag{2}$$

Where,

S^2= Variance of the fundamental sampling error.

M_L= Mass of lot.

M_s= Mass of sample.

d95= Diameter below which are 95% of the particles.

K= Constant that depends on mineralogical composition (*c*), density of the component of interest (λ_m), size distribution (*g*), form factor (*f*), and release level (*l*).

If the size of the lot to be sampled is large, the formula is simplified, leaving:

$$S^2 \approx K\, d95^2 \frac{1}{M_S} = \frac{f g l\, \lambda_m}{c} d95^2 \frac{1}{M_S} \tag{3}$$

With the characteristics of our cullet, we have obtained a curve that relates the standard deviation of that fundamental error with the considered sample size. It has been defined *d95*= 2,5cm, *c* =0,00005, *l*=1, g=0,25, *f*=0,09, λ_m =2,5g/cm3. From 50 kg of sample size, the reduction of the value of that standard deviation is irrelevant.

A sample size of 15x5=75 kg has been defined, giving a value of *S* = 0.5 which is considered as acceptable. The value of the standard deviation obtained with the 10 kg of sample used in the previous control method, *S* = 1.36, shows an important reduction of the standard deviation of the fundamental error value.

3.3 Mechanical elements for sampling

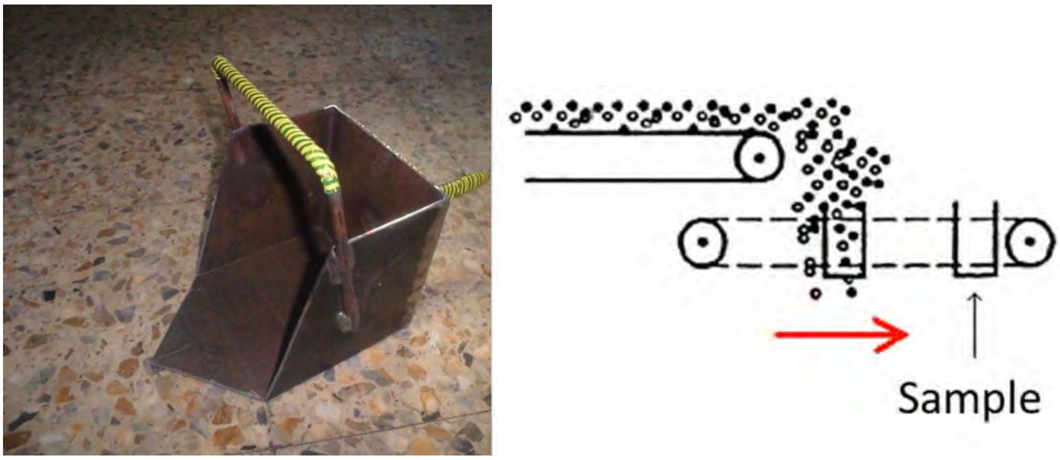

Fig. 3. (a) Dust collector designed by the engineering section; (b) Schematic design of the automatic system for sampling on the conveyor belt.

The trucks are unloaded in the "truck hopper 3" to climb to the tower of cullet by the belt S21. During the unloading, 5 different 15 kg samples are collected in each truck, each at different times of the unloading to try to avoid segregation through stratified sampling, and using a shovel designed at the factory to avoid losing parts of cullet when having in all its dimensions of 3x*d95*, Fig. 3 left.

As part of the implementation of the control process, it is proposed to install an automatic sampling system at one of the belt unloading points S21, see Fig. 3 right. This collection system would be accompanied by a vibrating table with 5 mm sifter to separate the fine material. All this measures would facilitate the inspection of the 75 kg of cullet by truck.

4. Results of new control plan

The result is a new, more efficient control system for the detection at the reception of the process of contaminant elements in the glass melting furnace, ensuring its maximum allowable limit. Fig. 4 summarizes the results of new control system from November 2016.

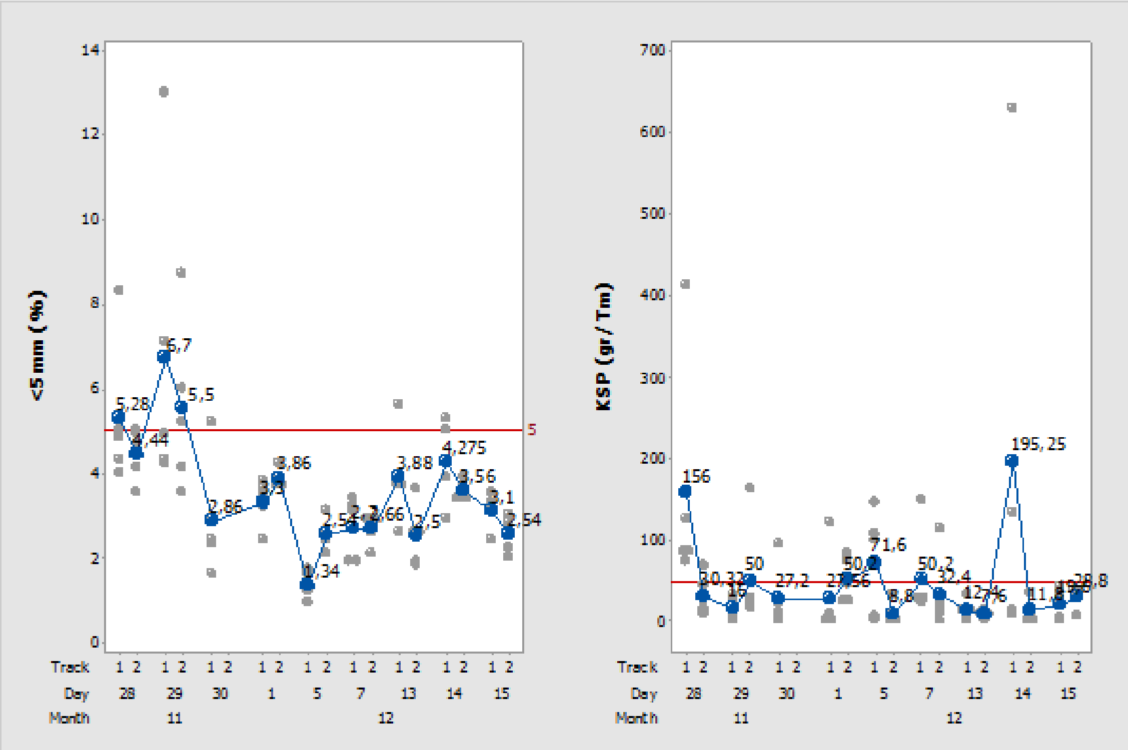

Fig. 4. (a) Summary of results of new control system, percentage of particle with diameter less than 5 mm; (b) KSP measures.

The decision to reject a truck is based on the fact that the average value of the sub-samples (5 in every truck) exceeds the limit for the parameter according to the criteria.

Respect to the KSP criterion, in three days, 28 November, 5 and 14 December. There is a situation in which there is only one rejected truck. These situations are serious enough to reject the batch. In some other days trucks appear with a mean value of 50.2 gr/Tm, that represents a less serious situation. If AQL = 10% is selected, in Normal sampling, with batches of up to 8 trucks, 2 trucks must be inspected and the batch rejected if both are rejected. Therefore, with this criterion no batch would have been rejected. In a later meeting of the engineering team, it was suggested that the criterion should be modified, imposing an AQL of 4%. With this change, the criterion of rejection of the batch would be that one single truck rejected. Application of this stricter criterion would lead to rejection of the batch in those 3 days of serious breach.

Applying the criterion referred to the percentage of fine material, trucks appeared above the threshold 5% in the initial days of system. However, this criterion no longer alarmed, since the supplier applied corrective measures.

5. Conclusions

The proposed plan control of cullet in the plant is defined, using the standard UNE-ISO 2958-1. It provides a useful control tool limiting risks to both the receiver and the cullet suppliers. It is based on a sampling at reception (at plant), which behaves better than previous one, and with a sufficient sample size to limit the sampling error.

The system can be improved with these options: a) Change in the AQL, decreasing from 10% to 4%, at least in the KSP parameter, or in several parameters. b) Multicriteria decision, establishing a combined decision based on the severity of non-compliance in all controlled parameters. c) Define the rejection decision of a truck based on the number of sub-samples that exceed the limit is greater than 2, 3 or 4.

Another procedure to take into account additionally is to raise a control at the plant of the supplier. In that case, "only" it is necessary to create a sample collection procedure that ensures a good representativeness of the batch, and with a size large enough for the fundamental sampling error to be within an acceptable value. In the case of control in supplier's plant, we propose to do a weekly control of the batch to be consumed the following week, separating in 5 more or less proportional parts, and taking a sample of 15 kg of each one with the Shovel described above, and performing the control at reception in our plant.

Acknowledgements

The authors gratefully acknowledge the support of the Verallia Chair in the University of Zaragoza and, partially, of the research group “Modelos Estocásticos”, supported by DGA and the European Social Fund..

References

[1] R. del Valle-Zermeño, J. Gómez-Manrique, J. Giro-Paloma, J. Formosa, J. M. Chimenos, Sci. Total Environ., 581 (2017) 897-905
[2] K. H. Esbensen, Chemom. Intell. Lab. Syst., 74 (1) (2004) 3–6
[3] S. P. Gundupalli, S. Hait, A. Thakur, Waste Manag., 60 (2017) 56-74
[4] ISO 2859-0-1995. Sampling procedures for inspection by attributes. Part 0: Introduction to the ISO 2859 attribute sampling system.
[5] ISO 2859-1-1995. Procedimiento de muestreo para la inspección por atributos. Parte 1: Planes de muestreo para las inspecciones lote por lote, tabulados según el límite de calidad de aceptación (LCA).
[6] A. W. Larsen, H. Merrild, T. H. Christensen, Waste Management & Research, 27 (8) (2009) 754-762
[7] A. Mitra, Fundamentals of quality control and improvement, John Wiley & Sons, New York, USA, 2016.
[8] W. Ran, F. Chen, Q. Wu, S. Liu, Math. Probl. Eng., (2016) 1-9
[9] B. Scalet., M. García, A. Q. Sissa, S. Roudier, L. Delgado, Publ. Off. Eur. Union, Luxembourg, 2013.
[10] M. A. Sironvalle, Introducción al muestreo minero. Instituto de Ingenieros de Minas de Chile, Santiago, Chile, 2002.
[11] P. L. Smith, A primer for sampling solids, liquids, and gases: based on the seven sampling errors of Pierre Gy. Society for Industrial and Applied Mathematics, Philadelphia (PA), USA, 2001.