



## **RETURN RATE IN DEPOSIT AND RETURN SYSTEMS STEREOLOGICAL ASSESSMENT ON ALUMINIUM PACKAGING**

## About the report

This report has been prepared as a result of discussions with European Envisage clients facing the ongoing debate in several European countries on the possibility of implementing different Deposit and Return Systems (DRS) for used beverage packaging.

The concept of *return rate* is a key element of those discussions. *Return rate* is the ratio of number of packaging units returned and reimbursed vs the number of packaging units sold with a deposit, and it is frequently an unknown figure. Everywhere there is a DRS in place, there is a difference between the total recycled amount of specific beverage packaging types and the intrinsic performance of DRS systems in operation, as measured by the number of units which are refunded when the packaging is returned to the system operator vs the number of units which are sold with a deposit.

## Disclaimer

While this report uses as an example for the suggested scientific methodology graphic material obtained in due time -several years ago- and with authorization in a German sorting plant, due to the time elapsed, the report does not make any assumptions or considerations on the current performance or results of the existing German DRS system DPG or any other system in operation in Europe.

## About the author

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## ABSTRACT

This paper stimulates discussion on the use of stereological procedures for waste content quantification, using as an example aluminium beverage cans present in bales of aluminium packaging sorted at a major packaging waste facility in Berlin. Unbiased pictures of aluminium bales were directly obtained by the author, and volume fraction measurements were processed with the ImageJ software widely used as standard image analysis method. For comparison, bales of beverage cans from a different recycling facility with a volume fraction of 100% ( $V_v=1$ ) are also shown. The aim is to determine the relationship between the -unknown- return rate of the deposit and return system in Germany (DPG) and the general fraction of aluminium packaging sorted in the DSD system. The relationship between volume fraction and return rate is heavily dependent on the relationship between beverage can waste and general aluminium packaging waste, which in the case of Germany is approximately 75/25. Beverage cans easily detected in the general aluminium sorted fraction - clearly visible- indicate a significant amount of non-returned cans within the deposit system. For the examples shown, a non-return rate of the order of 18% was estimated, in line with the performance of other mature DRS systems in Europe. A universal relationship between deposit return rate and volume fraction of beverage cans in the general fraction independent of total amount of aluminium waste processed is also established. We propose the term **wastereology** for this type of research.

**KEYWORDS:** *quantification, aluminium, stereology, deposit, packaging, return*

## INTRODUCTION

Separate collection and recycling of used packaging is widespread practice in Europe to decrease uncontrolled waste disposal and littering, and legislation is currently reviewed at EU and member country level. Circular Economy regulation, the Single Use Plastic Directive (European Parliament and Council, 2019) and the revision of Packaging Waste Directive (European Parliament and Council, 1994) are key examples.

A consistent improvement of used packaging recovery has been achieved throughout the continent, but limitations detected by the scientific community have basically to do with the lack of generally accepted measurement tools, especially for “recycled” amounts; in fact the EU effort to define waste collection and recycling targets has not been matched by a parallel effort to define standard measurement techniques to verify their fulfillment, and different countries have measured the amount of recycled material with their own parameters.

Deposit and return systems -DRS- for used drinks packaging are in place in several countries in Europe, and this paper uses as a case study the amount of beverage cans returned within Deutsche Pfandsystem (DPG), the German deposit and return system fully implemented in Germany in 2006.

Environmental NGOs claim that DPG collects almost every beverage can (>99%) consumed in Germany. Should this be correct, metal bales coming from the DSD (the public all-materials packaging recycling system Duales System Deutschland) should not contain beverage cans (for the purpose of this paper, beverage cans littered or present in unsorted waste – which basic common sense advises that under no circumstance can be zero- will be neglected). The mismatch of the results of this paper to the claim expressed above led to the idea that stereological measurements might help to quantify such difference.

This paper proposes the use of stereological procedures for waste content quantification. Stereology determines three-dimensional geometrical parameters from two-dimensional measurements in a variety of sections; it is a basic science extensively used in materials and biological research (Howard and Reed, 1987; DeHoff and Rhines, 1968; Aballe, 1996) and results can be processed through any standard image analysis procedure. To our knowledge, there are no published examples which address the question of waste quantification of this type with a similar method and for that reason we propose the term **wastereology**.

Different countries have significantly different beverage can per capita consumption. In Germany, the figure is rather low: aluminium deposit-bearing packaging represents approximately 0.15% of all packaging consumed (16Mt) 5% of deposit bearing packaging, and 25% of aluminium packaging recycled. In contrast, in other countries (eg Finland, Spain) most aluminium packaging recovered either with or without DR systems are aluminium cans. As an example, recently released figures for Spain (ARPAL, 2022) indicate that beverage cans represent 80% of all aluminium packaging recycled

Aluminium cans have been selected as the current trend for beverage cans around Europe is to be manufactured in aluminium, but steel beverage cans in steel bales could equally be analyzed. A more detailed description of the general quality of the metal bales examined for this paper has already been published (Aballe, 2014).

For simplicity, we will use the following figures as orientative of the quantities involved: according to data from the German environmental agency UBA, some 100,000t of aluminium packaging are recycled every year. Of that quantity, 25,000t are subject to deposit (aluminium beverage cans) and 75,000t are non-deposit packaging. Beverage cans subject to deposit should not be present in the aluminium fraction of the general packaging collection. Thus it makes sense to assess whether and how much goes into the aluminium fraction recovered by the DSD at sorting plants.

A preliminary calculation is necessary to define the relationship between return rate within the deposit system and volume fraction of beverage cans in the general fraction.

For ease of representation in the following, we will estimate that all aluminium beverage cans are recovered (either within the DRS or in the general fraction) neglecting the amounts of cans either gone in the unsorted waste fraction or littered. We are aware that this assumption means that the return rate will actually be overestimated, but we will not approach its estimate in this preliminary paper.

The following parameters are involved:

- b*** share of deposit bearing beverage cans consumed, and as advised above, assumed to be recycled, among all aluminium packaging recycled. In our case, ***b* = 0.25**
- 1-b*** share corresponding to non-deposit packaging.
- v*** volume fraction measured experimentally in the general fraction bales.
- r*** return rate for deposit bearing beverage cans (eg ***r* = 0.9** means 90% of the cans are returned via DRS)

We have derived the following relationship:

$$(1) \quad r = (v-b) / b (v-1)$$

For easier understanding, the relationship is shown graphically in Figure 1. 100% return means all cans put on the market are returned via deposit, and no cans are present in the general fraction, and the opposite case: all cans returned via DSD and none via DPG would mean 25% of the aluminium fraction would be beverage cans.

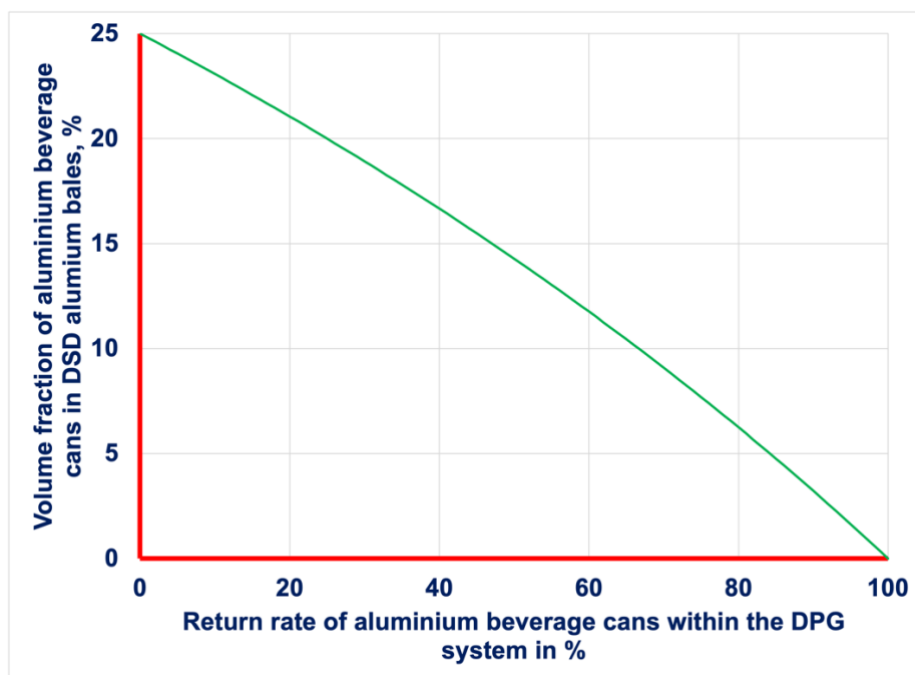


Fig 1.- Volume fraction of beverage cans in aluminium bales, %, vs return rate of beverage cans within the deposit system in the German DPG, in %

## EXPERIMENTAL PROCEDURE

In order to verify the presence of aluminium cans in the sorted aluminium fraction, the author took pictures without restrictions, of the sorted steel and aluminium fractions in the course of a technical visit to the Mahlsdorf packaging sorting plant in Berlin thanks to the courtesy of the plant management; all metal bales of recovered steel or aluminium packaging clearly contained beverage cans. For the evaluation and discussion, the date when the images have been obtained, September 2013, is relevant.

We measured the area fraction parameter  $A_A$ , (the area occupied by the object to be measured) in this case the visible part of beverage cans, in relation to the total area observed; this is the basic relationship used in stereology and it is equivalent to the volume fraction  $V_V$  of the relevant component. For a relative measurement, once the area to be measured is highlighted (we used the universally known image analysis program Image J)  $A_A$  equals the pixel ratio in the same field. Of the different fields observed which correspond basically to the visible face of the whole bale, two of them have been selected, figures 2 and 3, corresponding approximately to the highest and lowest values obtained in the series. Pictures were taken manually with a Canon 300D SLR camera and were not edited; the purpose of the exercise was not to single out beverage cans, but rather to have a sample of different bales in the stack while avoiding bias due to selection of the field of view.



Fig.2. Bale of sorted aluminium packaging. Volume fraction of beverage cans = 6,9%



Fig.3. Bale of sorted aluminium packaging. Volume fraction of beverage cans = 4 %

For comparison, Fig. 4 shows several bales of previously sorted aluminium cans compacted to maximum density in a specialized metal recycling company ready for sale as “top quality aluminium UBC”. 100% of the bale are aluminium cans and basically no free space, which can be taken as the standard:  $A_A = V_V = 1$ .



Fig.4 Bales of sorted used aluminium cans as top quality aluminum UBC. Volume fraction = 100%

## RESULTS AND DISCUSSION

A metal bale is not a fully compact body such as, for example a metal alloy with particles (Rhines & Aballe, 1986) thus the question of volume fraction might be discussed. When, as in this case, bales correspond to crushed packaging, the amount of free space or “holes” is also a variable to be considered, but we propose to consider their influence negligible in a first approximation; as all package types have “holes” (metal packaging do not exhibit a uniform density) that consideration is not taken into account, namely for the purpose of this paper, it is not relevant.

Figs. 2 and 3 were analyzed with the well-known image analysis program ImageJ, and yielded values of  $A_A$  of 0,069 and 0,040 respectively, in other terms 4% and 6,9% of the surface (thus volume) were beverage cans. Other fields are similar with values between these two examples, but as there are no statistical claims a couple of examples is enough.

If 99% of aluminium cans were collected via DPG in Germany, only 250 t of aluminium cans would be present in the DSD aluminium fraction - a volume fraction of the order of 0.3%, more than an order of magnitude difference- neglecting, as advised, the amounts present in unsorted waste. Values obtained from figs 2 & 3, namely 6,9% and 4%, are equivalent according to (1) to return rates of 77.8% and 87,5% respectively.

Taking into account that this is a very limited sample and extracting a more general conclusion would require systematic sampling and periodic analysis, our results in figures 2 & 3 show that around 5,5% of the aluminium collected by DSD (in this specific case) were beverage cans. This would extrapolate to a total amount of 5500 t of beverage cans, a non-return rate of 17% of the quantities consumed, a figure consistent with other mature European DRS systems for even longer periods.

It would be interesting to verify the accuracy of this estimate if the DPG system released the number of returned cans - a figure in theory known, as every can sold collects 0,25€ and every can returned receives back the same amount of 0, 25€ but in practice subject to confidentiality limitations - for the year considered, given the considerable time elapsed since these measurements were taken.

That is what, for example, is done in Norway, where return rates are made public yearly by the Norwegian deposit system *Infinitum*; Norway recently surpassed 90%, after more than 20 years of operation where return results remained stable around 85% for a long period, and of the same order are return figures in Sweden after 35 years in operation; while on a first look this paper could be taken as critical with the German system for the lack of data, paradoxically an experimental verification of the data found in this paper could show that DPG, with 7 years in full operation in 2013 might actually have outperformed them. Perhaps this discussion could stimulate such release.

Much remains to be discussed, especially from the points of view of sampling, statistical analysis and especially the possibility to carry out regular measurements in an automated way.

With these limitations in mind, to our view stereology can contribute to establish simple and accessible procedures for verification of recycling performance and might stimulate other application in the waste characterization area. That is why we propose to use the word **wastereology** to define this type of procedure.

## CONCLUSIONS

Simple stereological evaluation of beverage cans which are clearly visible at naked eye on the surface of sorted general fraction aluminium packaging bales indicate a significant proportion of non-returned cans within the Deposit and Return System (in this particular example DPG).

The considerations on the amounts of deposit packaging present in the general fraction, as described in equation (1) could be equally applied to other packaging formats and materials subject to DRS (e.g. PET bottles, in the hypothetical case that there were separate PET packaging sorting) or measuring methods, including complete characterization, sampling and weighing of the concerned fractions.

For the same reason they are equally applicable to other market or country conditions with different DRS vs non-DRS relative share of specific packaging materials and formats.

## ACKNOWLEDGEMENTS

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