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PREFACE

International Conference on Waste Recycling aims to stimulate intersectoral collaboration by gathering specialists highlighting problems related to industrial pollution, and indicate the right direction to find the solution to improve the quality of environment and life in V4 region and European area. Such cooperation strengthens the V4 partnerships in environmental research and waste recycling, delivering inter- and multi-disciplinary knowledge transfer in science and technology.
Jubilee Waste Recycling XX conference hosted by Institute of Geotechnics of Slovak Academy of Sciences follows the successful series of conferences focused on waste recycling (Waste Recycling I-XIX). From 1996-2012 the conference was organized by consortium of three Partners: Institute of Environmental Engineering, VSB-Technical University, Ostrava, Czech Republic; Cracow University of Technology, Krakow, Poland and Institute of Geotechnics of Slovak Academy of Sciences, Košice, Slovakia. In 2013, for the first time, the consortium extended the engagement of all V4 countries by involving the Hungarian partner Institute of Raw Material Preparation and Environmental Processing, University of Miskolc as a member of WR board, organizing and programme committees. Moreover, industrial partners from V4 region regularly participate at the conference. Industrial activities (mining, mineral processing and metallurgy) in V4 region have caused following environmental issues: air, water and soil pollution from mining in Upper-Silesian coal basin (CZ/PL), mineral processing, metallurgy industry in Eastern Slovakia, bauxite processing for alumina production (SK/HU). As transboundary pollution does not know physical or political borders, the elimination of such pollution should not be limited to the individual countries. Thus the solution of such problem requires collaborative approach of all parties.

The main topics of the conference are:

- **Recycling and utilization of industrial waste** (metallurgical, power-engineering, mechanical engineering, chemical industry, electronics, end-of-life vehicles, demolishing waste, mining waste and tailings, etc.).
- **Recycling of biowaste** (agricultural, forest, food-processing and municipal waste).
- **Critical raw materials** from secondary resources.
- **Recycling and remediation** of contaminated areas & acid mine drainage.
- **Waste water treatment** technologies.
- **Adsorbents** for complex water treatment.
- **Business activities** in waste recycling.
- **Legislation issues** of recycling and waste utilization.

International Conference on Waste Recycling provides the unique platform for scientists, policy makers, students, post-doc fellows, engineers, and organizations to better understand the underlying fundamental principles, current state of the art, and future needs and tasks of waste recycling and environmental remediation techniques.

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CONTENTS

SAMPLING AND ANALYSIS OF PRINTED CIRCUIT BOARDS

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Abstract
Determining the actual (precious) metal content of a lot or shipment by statistically and analytically accurate means to obtain a representative sample. The samples were analyzed to determine the gold content by atomic absorption spectrometry (AAS). The printed circuit boards (PCBs) of mobile phones are considerably heterogeneous materials with the high content of gold. The test sample designated for the chemical analysis of must truly represent PCBs from which was taken. The aim of this study was to develop acceptable sampling procedure to investigate the composition of heterogeneous printed circuit boards; the influence of particle size on the precision of chemical analysis of PCBs from mobile phones has been investigated. Chemical analysis of gold content in the sample with grain size ($d \leq 200$ μm) was 475g.t^{-1} and dispersion was 514.25, which showed the highest accuracy chemical analysis.

Keywords: *sampling, electronic scrap, PCB, mobile phones*

Introduction

E-waste is classified as hazardous material therefore should be managed properly. However, the presence of precious metals (PMs) in e-waste such as gold (Au), silver (Ag), platinum (Pt), gallium (Ga), palladium (Pd), tantalum (Ta), tellurium (Te), germanium (Ge) and selenium (Se) makes it attractive for recycling. Sampling is difficult for e-waste composition analysis due to the inhomogeneous and composite nature of the materials. Large numbers and various kinds of small of components are attached to PCBs. Generally, PCBs are crushed into smaller sizes (less than 1–2 mm) and various techniques including magnetic, electrostatic, electrowinning, and selective dissolution are implemented to separate the components. PCBs from mobile phones have higher (34.5%) copper contents compared to personal computers (20%) (Khaliq et al., 2014; Kamberovic et al., 2009; Jaščišák et al., 2017). Sampling and assaying is necessary in order to determine the composition and content of precious metals in the e-waste stream, and to ensure that the optimum process is used to recover precious metals. Laubertova et al. (2014) have recently shown sampling in Slovak copperworkers, Kovohuty, a.s. Krompachy Figure1. Sampling in SAFINA (Safina), Czech company is followed: The precious metal containing material is pretreated and subsequently homogenized in a sampleable form. By oxidative combustion or thermal annealing without access of air in annealing ovens at 850°C, the material is devoid of all organic matter and moisture at this stage. After this treatment in the furnaces, the material is crushed and ground in special mills on a fraction of a grain size of less than 0.4 mm. An analytical sample weighing about 100 g, which is the result of sampling, must correspond to the composition in the whole volume of the treated material, whether it is a few tons or just a few kilograms. The sample for analysis has a grain size of less than 0.2 mm and is prepared by milling on a vibrating disc grinder, screened on screens and, after grinding the whole, divided into eight portions of the same weight and the same composition Figure 2.. Sampling e-scrap in Boliden Rönnskär (*Electronics for all* , 2017), Before arriving at Rönnskär, the e-scrap undergoes pre-processing in the form of dismantling and crushing. Glass, a certain amount of plastic, and iron and aluminium are also separated out, because it is the copper, gold and silver content that has value for the smelter. All of the smelting materials are sampled before entering the processing line. This sampling work is important in determining the metal content of the material and the analysis forms the basis for the payment received by the supplier. The sampling plant contains a heat-hall for containers and equipment for unloading material from containers and big bags. An e-scrap shredder crushes the circuit boards that are delivered whole and the material lots are then sampled in the stream sampler and delivered to a storage facility where they are mixed before smelting. Umicore (*Weighing and sampling, 2017)* does not grade individual boards itself, but relies on its suppliers to do this based on: Physical composition of the boards; and Value of precious metals. When PCBs are received, they use a sampling and assaying procedure for the identification of the exact content of precious, base, minor metals and plastics contained in the shipment. Multi-stage crushing and dividing to <1 mm, pulverizing and smelting. Sampling in Aurubis (*Recycling, 2017)* Figure 3. Due to the inconsistent final sample treatment of modifications of the electronic waste experimental part of the work is focused on study of influence of the sample granularity to determine the gold content in PCBs of mobile phones.

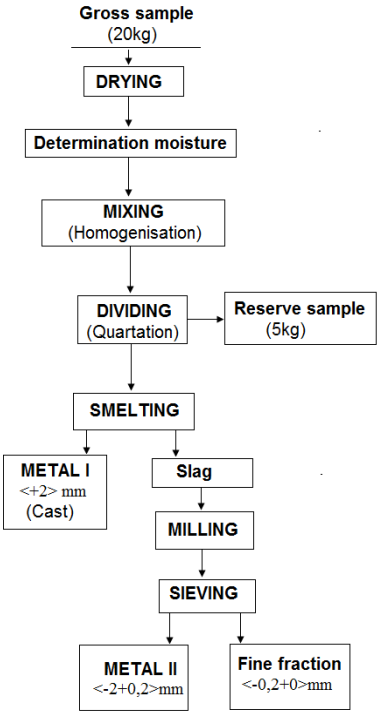

Figure 1. Kovohuty, a.s. Krompachy

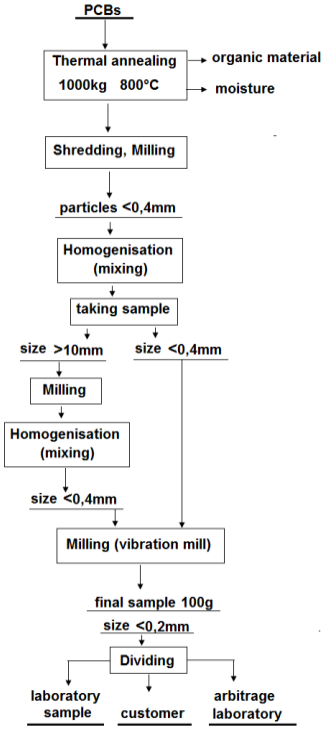

Figure 2. Safina

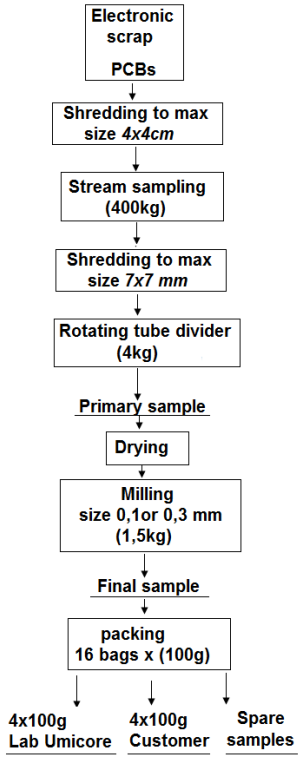

Figure 3. Aurubis

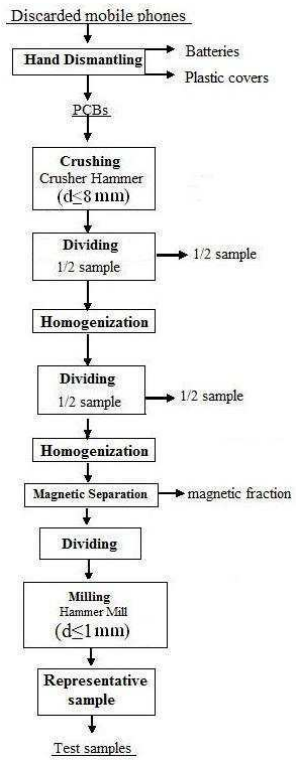

Figure 4. Sampling of mobile phone PCBs

Materials and methods/Area description

The input material used in this work was collected from different kinds of discarded push-button mobile phones as demonstrated Laubertová, et al. (2016). About 10.30 kg of collected mobile phones were used for the experiment. Remaining printed circuit boards were used for the experiment (2 kg). The crushing operation was carried out in the

crusher hammer (type SK 600) fraction (d≤8000μm). The sample of 1 kg was obtained by hand quartering, which was then divided 3 times by a divider. The magnetic separation was carried out to remove the magnetic fraction from the sample. Representative samples were milled under 1 mm in a hammer mill (type Hamilton Mich 49419) subsequently sieved to the grain fractions: (d≤1000μm) and (d≤200μm). The obtained 1g test sample from each fraction were analysed for the determination of copper by atomic absorption spectrometry (AAS) (Varian Spectrometer AA 20+). The fraction (d≤2000μm) was also used for determination content of Cu.

Results and discussion

The results of the chemical analysis (mean) of the determination of Au (in %) in the three grain fractions of PCBs are shown in Table 1. The individual grain fractions were performed and the mean value, Standard Deviation SD, Variation Range R, and Coefficient of variation V_x were calculated. Statistical data of chemical analysis of both grain sizes as the Standard Deviation SD, Variation Range R, and Coefficient of variation Vx was shown in Table 1. The influence of PCBs granularity on the accuracy of chemical analysis and samples were also subjected to observation by optical microscopy using Dino-Lite ProAM413T shows Figure 5.

Table 1. Comparison of statistical data for different grain fractions

Statistical characteristics for Au	Grain size (μm)		
	(d≤2000)	(1000≤d≤200)	(d≤200)
Mean ($g.t^{-1}$)	387.68	141.25	475
dispersion	10378.86	1298.21	514.25
SD	101.87	36.03	22.68
R	305.09	90	60
V_x	26.28	25.51	4.77

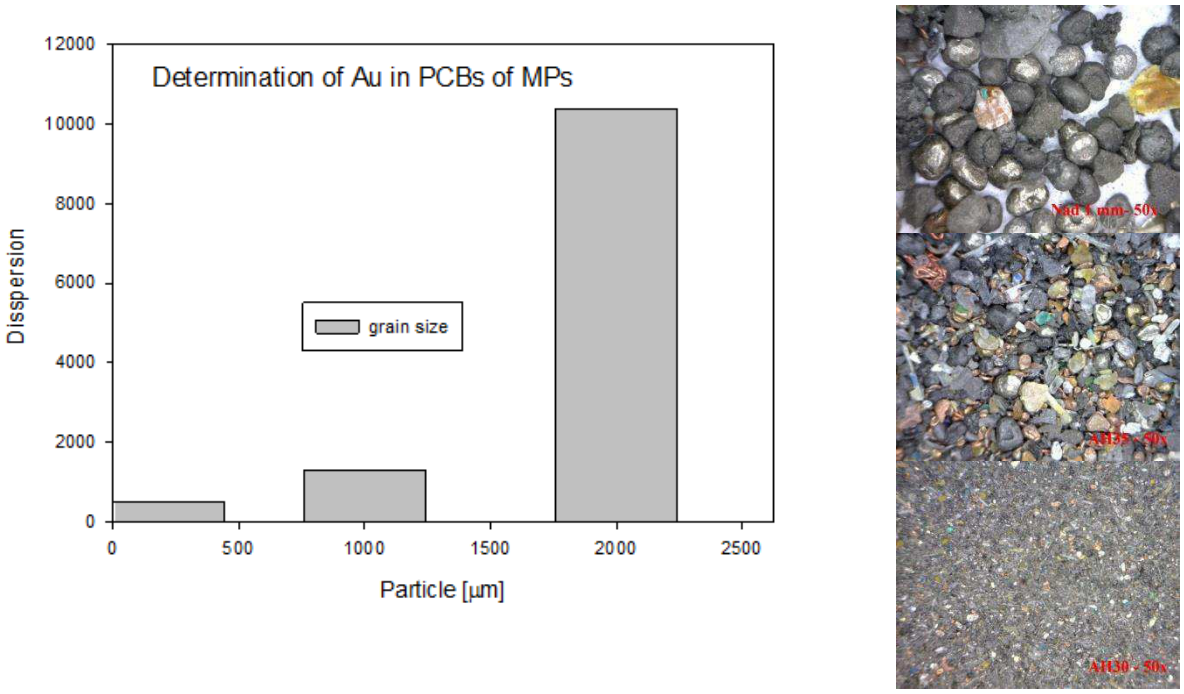

Figure 5. The influence of PCBs granularity on the accuracy of chemical analysis and particle fraction (d≤2000 μm), (1000≤d≤200 μm) and (d≤200 μm) (50 zoom)

Conclusions

In this work the influence of representative samples about different grain size on the accuracy of chemical analysis of printed circuit boards from mobile phones was studied. From collected MPs, 10% MT was taken from which

batteries and plastics were removed. The printed circuit boards were mechanically treated (crushing, milling) and subsequently homogenized. From a representative sample by dividing (quartertering) sampled laboratory samples was subjected to chemical analysis (AAS method) to determine Au content. On the basis of the statistically evaluated results, it has been found that the greatest impact on PCBs chemistry has a granularity. In conclusion, it can be argued that the lower the granularity, the lower the scattering. The results were subject to a smaller error, i.e. were more accurate. From the conclusions of the experimental work, the lower the grain size of a representative sample for chemical analysis, the higher the accuracy of the determination of the metals in the sample. Figure 4 shows designed flowsheet of PCBs sampling.

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