Recommendations for Good Working Practice

Plastic recycling – activities involving hazardous substances and biological agents in the material recycling of plastics

baua: Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

Baden-Württemberg

HESSEN

IFA Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung

BG RCI Berufsgenossenschaft Rohstoffe und chemische Industrie

bvse dasRECYCLINGnetz

Recommendations for Good Working Practice

Plastic recycling – activities involving hazardous substances and biological agents in the material recycling of plastics

Recommendations for Good Working Practice
“Plastic recycling – activities involving hazardous substances and biological agents in the material recycling of plastics"

The recommendations for good working practice have been drawn up by the Plastic Recycling Working Group on the basis of the LASI/ALMA Recommendations LV 32.

Publisher: Federal Institute for Occupational Safety and Health (BAuA)
Friedrich-Henkel-Weg 1-25
D-44149 Dortmund
www.baua.de

Editor: "Plastic Recycling" Working Group

Dipl.-Ing. Gerhard Ott (Chair)
LUBW State Institute for the Environment, Measurements and Nature Conservation Baden-Württemberg
Baden-Württemberg
Hertzstraße 173
D-76187 Karlsruhe

Dipl.-Ing. Katja Vossen
Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA)
Alte Heerstr. 111
D-53757 Sankt Augustin

Dr. Ralph Hebisch
Federal Institute for Occupational Safety and Health
Friedrich-Henkel-Weg 1-25
44149 Dortmund

Dr. Gunter Linsel
Federal Institute for Occupational Safety and Health
Nöldnerstraße 40-42
10317 Berlin

Erolf Brucksch
Regional Council Kassel
Specialist Centre for Product Safety and Hazardous Substances
Ludwig-Mond-Straße 33
34121 Kassel

Dipl.-Ing. Sybille Simon
German Social Accident Insurance Institution for the raw materials and chemical industry
Magazinstraße 15-16
10179 Berlin

Dr. Thomas Probst
Federal Association for Secondary Raw Materials and Disposal (bvse)
Hohe Straße 73
D-53119 Bonn

Title picture: Federal Institute for Occupational Safety and Health Dortmund

As at: February 2012

Contents

1 General remarks

If workers perform activities involving hazardous substances or if hazardous substances are released, the employer is obliged under the Hazardous Substances Ordinance [1] to perform a risk assessment according to the Occupational Safety and Health Act and to take measures to ensure the safety and protect the health of workers. The same procedure also applies under the Biological Agents Ordinance (BioStoffV) [2] to activities involving biological agents.

When the protective measures are being laid down attention must be paid to the order of priority: substitution (replacement by less hazardous substances or processes), technical minimisation of the exposures, organisational measures and personal protective measures. For hazardous substances with an occupational exposure limit the compliance with these must be established by means of workplace measurements (TRGS 402 [3]), where no equivalent assessment procedures are described.

The recommendations for good working practice “Plastic recycling – activities involving hazardous substances and biological agents in the material recycling of plastics" constitute a sector-specific aid for the risk assessment and for the selection of suitable protective measures during activities for the recycling of plastic waste products. They support the employer in his conduct of the risk assessment and effectiveness check of protective measures. In their formulation, the previous LASI publication LV 32 [4] from the measuring bodies of the federal states of Baden-Württemberg and Hesse, the Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA), the Federal Institute for Occupational Safety and Health (BAuA) and the Bundesverband Sekundärrohstoffe und Entsorgung (bvse – Federal Association for Secondary Raw Materials and Disposal) was revised by including new data.

The recommendations for good working practice may be applied in connection with hazards due to released particles as standardised working procedures under TRGS 400 [5] on the basis of the Hazardous Substances Ordinance [1]. The protective measures specified have been compiled on the basis of workplace measurements under TRGS 402 [3]. When they are applied it may be assumed that the limit values for inhalable and respirable particles according to TRGS 900 [6] and Annex I No. 2.3 Para. 2 of the Hazardous Substances Ordinance [1] have been complied with.

In order to ensure the permanent effectiveness of the measures taken, they must be regularly checked. This can be done with the help of the present recommendations for good working practice. Workplace measurements are then normally not required.

Plastics, and in particular biologically contaminated plastics from collection in a Dual System, may be contaminated with biological agents such as moulds, bacteria or endotoxins. The present recommendations for good working practice include supplementary instructions for the risk assessment during activities involving biological agents [7].

2 Scope

These recommendations apply to facilities which recycle plastics occurring

- as commercial waste and production waste or
- as waste under the Packaging Ordinance and from collection via dual systems (e.g. DSD, Landbell, ECO-Punkt, Belland, Redual, …)

and are passed on for material recycling.

The recommendations apply to workplaces in facilities which store, sort, crush, grade, wash, dry, separate, mix, compound, granulate or melt/extrude standard thermoplastics (see also Figure 1). Individual process stages may be simplified or dispensed with entirely. The present recommendations also apply to the recycling of technical plastics where the individual stages of the recycling process are the same.

Plastics within the meaning of these recommendations for good working practice are mass thermoplastics such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET), which account for about 90 % of the total recyclable yield. The remaining fraction comprises technical plastics such as polyamides (PA), polycarbonates (PC), acrylonitrile butadiene styrene (ABS), polybutylene terephthalate (PBT) etc. Articles and products are then manufactured from the plastic waste. This may, for example, be noise baffles, high-quality panels or PVC windows.

Cleaning and maintenance jobs, where these are part of the day-to-day working sequence (e.g. cleaning jobs at the end of a shift or with a switch to another batch), also fall within the scope of the present recommendations. Where cleaning and maintenance jobs are performed in the context of operational disturbances, additional protective measures must be taken if necessary.

The scope of the recommendations does not encompass recycling as a raw material by thermal degradation or solvent processes and recycling as an energy source. For recycling as a raw material the plastic is broken down into its source materials, e.g. to extract methanol. Recycling as an energy source arises, for example, in the production of cement or steel, the plastic waste being used as an energy source or reducing agent.

3 Information gathering

Plastic waste comprises industrial waste and waste from returned empty containers and collections in the Dual Systems. Material recycling of plastics is qualitative processing which can be conducted manually, partly automatically or fully automatically. Undesirable substances such as metal or other extraneous plastics are removed fully as far as possible.

3.1 Working processes and activities

In practice given the results available it is not necessary to distinguish in the process stages according to which plastics are recycled. Figure 1 shows an overview of the process sequence. For industrial waste and waste from returned empty containers and collections under the dual systems the process stages are essentially the same as those for cleanly separated production and processing waste products, individual sorting and cleaning steps being dispensed with although for the latter.

Below the individual working steps of such an installation are described in greater detail:

Material feed

Depending on the facility and the nature of the plastic waste products delivered these are stored in the open or indoors. Using forklifts the waste is then fed to a belt, which passes it on for sorting or directly for grinding/shredding. In individual facilities the material feed is partly manual.

Sorting

The plastics are either sorted manually or using automated procedures. The aim of the sorting is to achieve the mostly purely possible sorted plastic fractions. Extraneous plastics and other interfering materials which do not belong in the fractions to be recycled are removed here. Metals are normally separated by metal separators which are often positioned at different points in the technological sequence.

In the case of manual sorting the workplaces are generally in sorting booths with a technical ventilation system. The belts with the plastic waste products to be sorted pass through these sorting booths. The workers separate the plastics manually according to fractions and at the same time remove the undesirable components.

In the case of automatic sorting the extraneous components are identified using optical and/or spectrometric detection techniques and they are then blown out in a controlled fashion from the material flow.

The degrees of purity achievable in the plastic fractions are comparable for manual and automatic sorting.

Some sorting operations come downstream of the grinding/shredding since the comminuted plastics can be separated from any extraneous substances still present by exploiting their physical properties (e.g. density). For this purpose additives (such as flotation aids) are sometimes added.

Grinding/shredding

This is taken to include all operations listed in Figure 1 under pre-comminution and comminution. Throughout this concerns operations performed by machines. The workers monitor to ensure that no malfunctions occur and service the machines.

During grinding and shredding the plastics to be recycled are comminuted to the point where they can pass to the subsequent process stages.

Washing

The plastic fractions are cleaned in large washing baths. Extraneous components adhering to the surface (e.g. paper, glue and dirt) are detached in this process stage, partly with the addition of washing agents, and at the same time separated off.

The workers essentially perform monitoring functions during the washing. In some cases the remove the extraneous substances from the washing baths by skimming.

The washed and dried ground materials may already be the end product of the recycling operation and are then finished immediately.

Mixing/compounding

The cleaned plastic fractions are mixed in a controlled fashion with additives to improve their properties or to facilitate further processing. For example optical brighteners or dyes can be added to achieve a desired colour in the subsequent product.

Mixing normally proceeds in continuous systems where the additives are mixed in automatically. In some cases (large-tonnage) mixers are also exposed to the plastics and additives and the mixture is removed after the completion of the mixing operation.

The additives are fed partly by hand from containers (e.g. paper bags).

Extrusion/granulation/melting/compression

Melting or compression gives rise to compact products from the plastic fractions (e.g. delineator feet). Sheeting is produced by drawing or blowing from the molten material or the granulate.

In extrusion the ground plastic fraction is passed through an extrusion screw at elevated temperatures. At the chopping point there arises the granulate with defined properties, which normally represents the end product of the recycling operation and is then available for further processing. Depending on the technological configuration of the extrusion operation granulates of different shapes and sizes are produced.

The workers have the task here of guaranteeing the trouble-free operation of the extruders. In particular the screens must be cleaned and regularly replaced. During extrusion malfunctions may occur. For example, if the extruder runs hot the plastic mass may "burn off", which means that chlorine-bearing compounds (such as HCl) may be released during PVC recycling. If such malfunctions occur proper operation must be restored while using personal protective equipment (especially respiratory protective equipment).

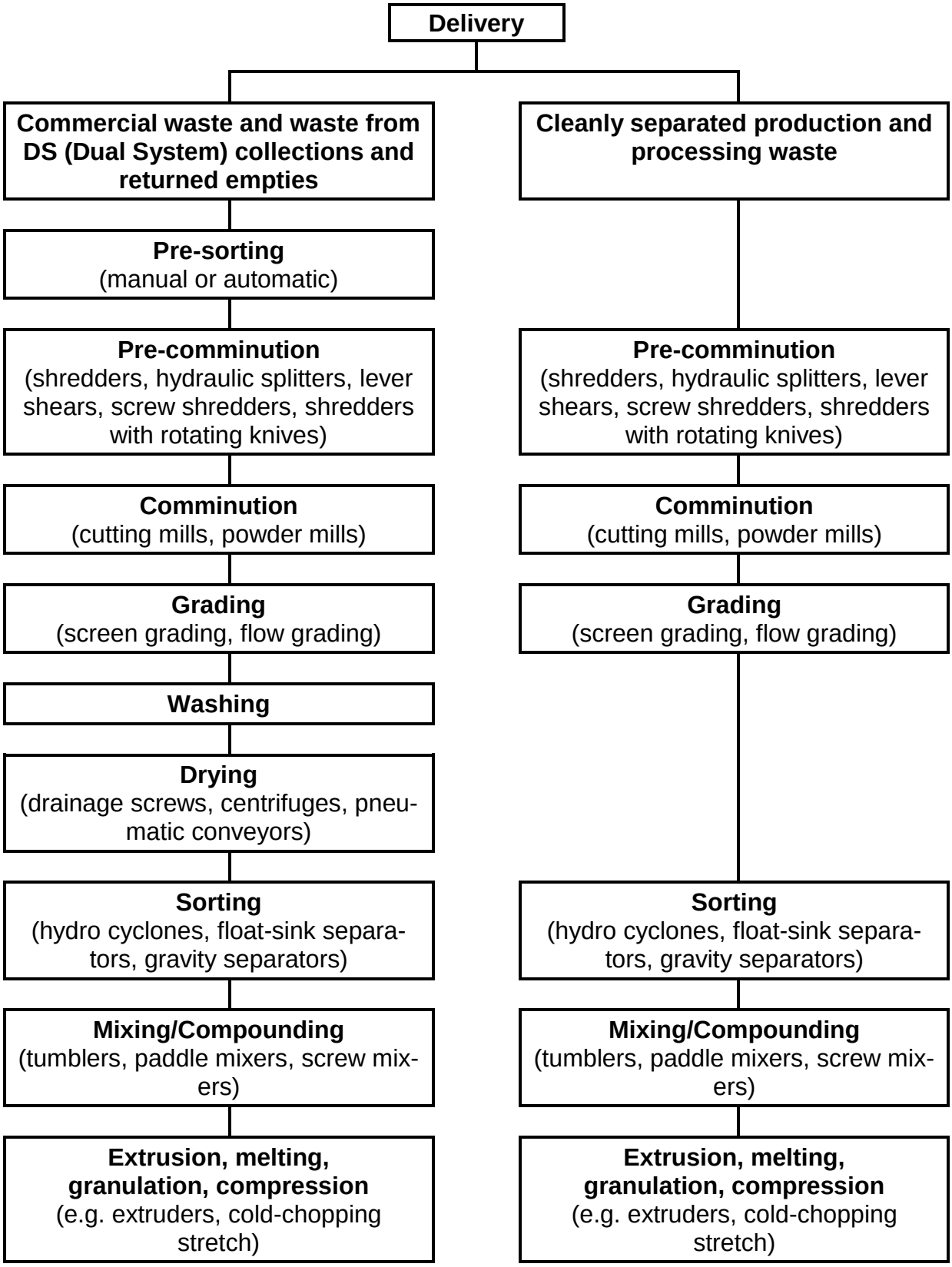

Figure 1: Process stages in the material recycling of plastics [8]

Finishing

The end products of the recycling facility (granulates or flakes) are poured into transport containers using automatic filling machines (normally big bags). Using forklifts these containers are transported from the filling machines to an interim storage or loaded directly onto transport vehicles.

The workers check the filling level of the containers, take occasional samples for quality control and replace full containers by empty ones.

3.2 Substances arising during the material recycling of plastics

During the material recycling of plastics both hazardous chemicals and biological agents may arise at the workplaces.

During activities conducted within the framework of the recycling respirable and inhalable particles are released. Furthermore it is possible that heavy metals and organic and inorganic gases and vapours will be released as decomposition products of plastics. In addition it must be assumed that the air is polluted by diesel exhaust from the delivery vehicles.

The processing of contaminated plastics may also lead to pollution of the air by biological agents, such as moulds, bacteria and endotoxins. These exposures must be evaluated independently of the hazardous substances.

3.2.1 Hazardous substances

- Airborne particles

During the treatment of plastic waste dust is released to differing degrees.

In addition defective, leaky transport lines or uncovered dosing and transport devices can lead to particle exposures. In particular operational disturbances, and maintenance and cleaning work may lead to an above-average exposure to particles.

Alongside the plastics to be recycled and their additives, the particle fractions often contain components which emanate from the original use of the plastic or from its transport and storage, and this is particularly the case when the installations are being charged or sorting is in progress.

For the respirable and inhalable particle fraction the occupational exposure limits are 10 mg/m³ and 3 mg/m³, respectively [6].

- Organic gases and vapours

During the thermal treatment of plastics, e.g. extrusion, organic gases and vapours may be released. Depending on the type of plastic and the temperature at which the materials are being processed, these may be monomers, volatile additives and a large number of different decomposition products through to carbon monoxide (CO) and carbon dioxide (CO_2) [9, 10]. During normal operation of the installations, i.e. with the exception of malfunctions, it is not necessary, however, to assume the emergence of a relevant quantity of decomposition products. This has also been confirmed in the examinations on which the present recommendations are based.

- Metals and metal compounds

During the manufacture of plastics metal compounds are sometimes used, e.g. as constituents of pigments, as flame inhibitors and as stabilisers.

Even if the use of cadmium is restricted or prohibited and the use of lead (especially in PVC products) tends to be in decline (substituted by Ca/Zn as a stabiliser), the air at the workplace may be polluted by lead and cadmium if particulate matter arises from the material being worked or from additives and this material has a relevant metal content. Table 1 gives an overview of the metals and their compounds which contribute to the pollution.

Pollution from other metals or their compounds could not be verified by measurement.

Table 1: Metals present in plastic which contribute to pollution

Metals and their compounds	Possible use [11, 12]	Remarks [13, 14, 15]
Cadmium	Stabiliser in PVC, pigment	Should be regarded as carcinogenic for humans (carcinogenic C 2). Plastics with more than 0.01 % Cd may not be placed on the market.
Lead	Stabiliser in PVC, pigment in PE	Known to be reprotoxic for humans (harmless to development) (R_E1), is cause for concern because of possible adverse effect on reproductive capacity (fertility) of humans (R_F3). Classified by the Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area as carcinogenic category 2 [16].

- Diesel particulate matter

Exhaust fumes from diesel engines are a complex substance mixture of gaseous and particulate fractions. The particulate fraction (known as diesel particulate matter (DPM)) is classified as carcinogenic (category 2 according to DFG) [16]. Gaseous constituents of the exhaust gases from diesel engines include, for example, nitrogen oxides and carbon dioxide.

Exposures due to diesel particulate matter may arise when plastic waste is delivered. It is frequently delivered in a hall. For this purpose the vehicles must enter the hall wholly or partially. The vehicles, which are licensed for travel on public roads, are often not fitted with diesel particle filters. During the delivery the doors of the hall are open. The engines are switched off during waiting times.

In the working areas the bales and bags delivered and the Big Bags filled, for example, with granulate, are often transported using forklifts. Use is made mainly of diesel-powered, gas-powered and electrical forklifts. According to TRGS 554 “Exhaust fumes from diesel engines“ [17] diesel-powered forklifts in enclosed working areas must be fitted with particle filters or the diesel exhaust fumes must be extracted directly at the point of origin.

For diesel particulate matter there is at present no health-based occupational exposure limit. In view of the carcinogenic effect it must be ensured under the Hazardous Substances Ordinance that the exposures are minimised in accordance with the state of the art.

3.2.2 Biological agents

During the recycling of plastic waste it may arise, in addition to pollution by hazardous substances, that biological agents are unintentionally handled, i.e. microorganisms may arise. These microorganisms are introduced into the recycling process with organic contaminants on the plastic material and, especially when airborne, they represent a hazard to workers as smear infection and as a result of cutting and stick injuries.

At the workplaces in the area where plastic waste is being recycled (e.g. material sorting installations, plastic treatment installations etc.) fungi, bacteria and viruses may basically occur. The classification of biological agents into risk groups is conducted according to the infection risk they represent. Experience has shown that in recycling facilities this involves mainly moulds and actinomycetes of risk groups 1 and 2, which may cause illnesses in humans. Effective prevention and treatment is normally possible. Possible toxic and sensitising effects of biological agents must be considered in addition in the risk assessment.

For the evaluation of the pollution due to microorganisms at the workplace suitable sum and lead parameters have been established in the past. In the area of recycling these are moulds and endotoxins. Endotoxins are structural constituents of gram-negative bacteria and can lead to inflammations of the airways or flu-like symptoms [18].

4 Assessment of exposure to hazardous substances

If during the material recycling of plastic waste the protective measures listed in section 5 are taken, no workplace measurements have to be conducted. The risk assessment for activities involving hazardous substances can be concluded in accordance with TRGS 402 [3] with the finding **"Protective measures adequate"**.

In order to take over this finding for the individual facility the documentation of the hazardous substances and the description of the activities and protective measures must confirm compliance with the protective measures described in these recommendations.

For the risk assessment of the individual working areas and activities the exposures given in Table 2 from the years 1996-2003 can be referred to. The workplace measurements conducted in the period 2002 to 2008 to a smaller extent to check the former LASI publication LV 32 [4] confirmed these results. For justification purposes reference should be made to the evaluation of extensive workplace measurements in Annex 1. The 95 percentiles were used.

Table 2 Overview of the shift averages identified in the material recycling of plastics (95 percentiles) [mg/m³]

Substance	Shift averages [mg/m³]
inhalable particle fraction	
all working areas	3.62
of which: material feed	2.05
sorting	1.48
grinding / shredding	6.63
washing	0.52
mixing / compounding	31.2
granulation / extrusion	1.36
finishing	1.43
miscellaneous	3.47
respirable particle fraction	0.88
lead	0.013
cadmium	0.0004

The occupational exposure limits for the inhalable and respirable particle fraction are complied with. For mixing and compounding this only applies if no powdered additives are added in open mixers.

For cadmium it is possible to derive an acceptance and tolerance concentration of 0.2 µg/m³ and 2 µg/m³, respectively from the cancer risk number [19] according to BekGS 910 [20]. The 95 percentile is between these two values. Based on the cancer risk numbers for cadmium one obtains for the 95 percentile (0.4 µg/m³) an additional cancer risk of 8×10^{-4}.

For lead the concentrations identified at 0.013 mg/m³ are substantially below the value of 0.1 mg/m³ [21], given in TRGS 505 "Lead".

During normal operation of the installations, i.e. with the exception of malfunctions, it is not necessary to assume the emergence of a relevant quantity of decomposition products (gases and vapours).

With the use of diesel particle filters (DPF) during the operation of forklifts no diesel particulate matter (DPM) is measurable.

If the present recommendations are applied other requirements of the Hazardous Substances Ordinance continue to apply, and in particular those on information gathering and the risk assessment for working areas of the facility not covered here in which activities involving hazardous substances are carried out and for which the present recommendations do not apply.

For other possible working areas of the facility reference should be made to relevant recommendations.

5 Protective measures for plastic recycling facilities

Below the protective measures are listed which have to be taken for the various activities in the area of the material recycling of plastics. When the required measures are implemented, the present recommendations for good working practice apply as a standardised working procedure according to TRGS 400 [5].

This considerably reduces the effort required for deriving protective measures within the framework of the risk assessment. Furthermore the present recommendations contain other instructions for the employer, such as additional hazardous substances information, including information on substitute processes, technical minimisation measures and other measures of substance-related occupational safety and health.

In addition the requisite measures for the use of diesel vehicles according to TRGS 554 [17] are listed.

Furthermore the requisite measures within the framework of fire and explosion safety and workers' skin protection are described in greater detail.

The additional remarks given in Annex 2 support the employer in the assessment of the exposures due to biological agents. The specifications of TRBA 214 [22] apply.

5.1 Measures to reduce the exposures to hazardous substances

For the application of the present recommendations the following conditions must be met. If they are implemented it can be assumed that the occupational exposure limits are complied with. It is not necessary to distinguish according to the chemical composition of the plastic being recycled. Similarly it is not necessary to distinguish with respect to the hazardous substance exposures between the recycling of commercial waste, waste from DS (Dual System) collections and returned empty containers, and between production and processing waste.

The machines and installations for plastic recycling must comply with the installation and operating conditions specified by the manufacturer. During intended use the safety and health protection of the workers must be ensured. During the erection and operation of machines and installations the risks which may arise from interactions with other items of work equipment, agents or the working environment must be taken into account. Work performed on machines and instalaltions may only be carried out by workers who are authorised to do so and capable of performing such work independently and safely or who are supervised during such work.

Covers mounted on the machines and installations and other protective devices which are intended to prevent release of hazardous substances may not be opened, removed or otherwise bypassed during operation.

At existing transport, filling or decanting devices the dropping heights must be minimised. Where necessary, flexible covers or encasements must be mounted.

At open mixers and installations in which powdered additives are added, an effective extraction system must be installed to prevent the development of dust and its spread into the working area.

Extrusion, blowing, deep-drawing and cold chopping installations must have an extraction system at the points where hazardous gases and vapours may escape into the workplace air. For working areas with extruders which run hot or may "burn off", personal protective equipment must be provided for the workers. At extrusion installations for

PVC appropriate gas filter masks (filter of type class B2P3 (P2) in combination with a suitable semi-/full-face mask) to protect against chlorine-bearing gases must be made available.

For transport jobs in the working areas preference must be given to the use of gas-powered or electrical forklifts. Gas-powered forklifts must be serviced regularly to minimise the exposure to carbon monoxide and must be set according to manufacturer's data.

The operation of diesel-powered forklifts without exhaust treatment system or particle filter is not permissible in wholly or partly enclosed working areas. If diesel-powered forklifts are used they must have an exhaust treatment system or a particle filter which meets the requirements of the FOEN (Federal Office for the Environment, Switzerland) filter list[1]. The exhaust fume emissions from the engines must be monitored in accordance with the provisions of TRGS 554, Annex 3. When new forklifts are procured a test must be performed according to TRGS 554, Annex 4 [17] to decide on the type of drive system.

Vehicles with diesel engine licensed for road traffic which are driven in wholly or partly enclosed working areas must be fitted with push-on particle filters or the vehice exhaust fumes must be collected directly at the exhaust pipe and conducted out of the working area (e.g. using push-on exhaust extraction systems).

Cleaning work, especially work to remove dust deposits, must be performed regularly. To avoid the swirling of particles as far as possible use must be made of industrial vacuum cleaners (dust class L).

The use of compressed air for blowing is only permissible if the locations to be cleaned are not accessible to industrial vacuum cleaners. In such cases basic cleaning must invariably be carried out beforehand using industrial vacuum cleaners. It is not permissible to blow-clean the floor.

When cleaning mixing and grinding devices and during operational disturbances where clogged installations have to be dismantled and cleared, particle-filtering semi-face masks of protection class P2 must be worn. The rules of the Berufsgenossenschaft (institution for statutory accident insurance and prevention) must be adhered to [23]. It is not permitted to wear burdensome personal protective equipment as a permanent measure instead of technical or organisational protective measures.

As far as possible it must be prevented that polluted air passes into adjacent, unpolluted working areas.

The workers must be equipped with safety shoes of protection category S2 according to DIN EN ISO 20345 [24] and suitable work clothing in the form of a body-covering working suit according to DIN EN 340 [25].

When opening bales suitable gloves must be worn – e.g. leather gloves – as must protective visors for the face. The gloves used must have been tested to DIN EN 388 [26].

For all working areas operating instructions must be drawn up. Workers must be given regular instruction.

Eating, drinking, smoking and the taking of snuff is not permissible at the workplaces.

[1] http://www.bafu.admin.ch/luft/00632/00639/00644/index.html#sprungmarke0_2

At all workplaces the principles for the prevention of hazards according to the Articles 8 to 11 GefStoffV must be complied with, see also TRGS 500 [27].

5.2 Fire and explosion safety

Because of the mainly combustible plastics to be processed there is a high fire risk in facilities which fall within the scope of the present recommendations. The particles released during the processing are mostly combustible and are explosive as a particle-air mixture under certain circumstances.

Under Article 5 of the Occupational Safety and Health Act [28] in conjunction with Articles 6 and 11 of the Hazardous Substances Ordinance [1] the employer must also identify the risk to workers from fires and explosions and take minimum operational measures of fire and explosion safety. In cases of doubt a fire safety report by an expert must be obtained.

Basically the specifications of the respective regional construction regulations and industrial construction regulations must be met with a view to fire and explosion safety. Further measures regarding structural, technical, operational and organisational fire and explosion safety may be necessary as the result of the risk assessment.

The formation of an explosive atmosphere is not to be expected if dust deposits are avoided in the working premises, if they are removed at appropriate intervals by moist and wet procedures or using suitable industrial vacuum cleaners (no compressed air) and if dust removal equipment is regularly cleaned and properly maintained.

Detailed instructions concerning fire and explosion safety can be found in TRGS 720-722 [29-31] and the Berufsgenossenschaft Information BGI 560 [32].

5.3 Dermal exposure

For workers in recycling facilities for plastics there is only a low risk, even with longer-term skin contact with airborne particles. This mainly concerns the hands in contact with contaminated surfaces. During sorting there is also a mechanical risk from cutting and stick injuries.

In the facility an activity-related skin protection plan must be drawn up and displayed. In the skin protection plan the necessary protection, cleaning and care measures must be allocated in a clear and comprehensible form to the corresponding jobs which are harmful to the skin. When drawing up the skin protection plan it is advisable to provide occupational medical support.

The aids listed in TRGS 401 [33] for estimating the risk and for selecting and evaluating personal protective equipment and skin protection agents must be referred to. The result must be documented.

6 Effectiveness check

When applying the present recommendations for good working practice the measures and requirements laid down in section 5 must be complied with.

At regular intervals or after modifications of processes and installations the functioning and effectiveness of the technical protective measures in place must be checked. In particular the intervals laid down by manufacturers for tests and services must be adhered to. All tests and repair measures on the installations must be documented.

The user of the present recommendations must check the validity of the conditions in the case of modifications to processes and otherwise regularly, and at least once a year, and he must document the result. This includes, among other things, a check of the unchanged validity of the present recommendations.

When these recommendations are being applied other requirements of the Hazardous Substances Ordinance shall continue to apply, especially those on information gathering and risk assessment for working areas of the facility not mentioned here where activities involving hazardous substances are carried out and for which the present recommendations do not apply.

The present recommendations for good working practice are available at www.baua.de. They are regularly reviewed and adapted to the state of technical and legal development. The user of the present recommendations should therefore always ensure that the current version is being used.

7 Literature

[1] Ordinance on the protection against hazardous substances (Hazardous Substances Ordinance - GefStoffV) of 26 November 2010 (BGBl. I p. 1643)

[2] Ordinance on safety and health protection at work involving biological agents (Biological Agents Ordinance - BioStoffV) of 27 January 1999 (BGBl. I p. 50), last amended on 18.12.2008 (BGBl. I p. 2768)

[3] TRGS 402: “Identification and assessment of the risks from activities involving hazardous substances: Inhalation exposure”, edition January 2010, corrected: GMBl 2011, No. 9, p. 175

[4] LASI publication LV 32: “Umgang mit Gefahrstoffen und biologischen Arbeitsstoffen bei der werkstofflichen Verwertung von Kunststoffen” *[Handling hazardous substances and biological agents during the material recycling of plastics*], Länderausschuss für Arbeitsschutz und Sicherheitstechnik (LASI) (2004)

[5] TRGS 400: “Risk assessment for activities involving hazardous substances”, edition: December 2010, GMBl 2011 No. 2 pp. 19-32

[6] TRGS 900: “Occupational exposure limits”, edition January 2006 (BArbBl. Issue 1/2006 pp. 41-55, last amended and supplemented: GMBl 2012 No. 10 pp. 193-194

[7] TRBA 400: “Guideline for risk assessment and for the instruction of employees in relation to activities with biological agents”, edition April 2006, BArbBl. 6/2006 p. 62

[8] R. Hebisch, A. Johnen, G. Linsel: "Stoffbelastungen beim Recycling von Kunststoffen", *["Substance exposures during the recycling of plastics"]* Sicherheitsingenieur 34 (2003), Issue 5, pp. 16-21

[9] J. Auffarth, E. Lehmann, J. Gmehling, V. Wölfel, K.-H. Rentel: "Stoffbelastungen bei der Kunststoffverarbeitung", *["Substance exposures during the processing of plastics"]* Publication Series of the Federal Institute for Occupational Safety and Health: Gefährliche Arbeitsstoffe (GA 43), Wirtschaftsverlag NW, Bremerhaven (1994)

[10] Berufsgenossenschaftliches Institut für Arbeitsschutz: "Flüchtige Zersetzungsprodukte von Kunststoffen*" ["Volatile decomposition products of plastics"]*; BIA-Info 3/99, Sankt Augustin (1999)

[11] Umweltstiftung WWF Deutschland: "Kunststoffe – Umwelt und Gesundheitsfragen" *["Plastics – environment and questions of health"]* (1995)

[12] J. Brandrup (ed.): "Die Wiederverwendung von Kunststoffen*" ["The reuse of plastics"]*, Carl Hauser Verlag, München (1995)

[13] EU Directive 67/548/EEC, Annex I: “Classification/packaging and labelling of dangerous substances”, Official Journal of the European Communities No. L 196 p. 1, last amended by Commission Directive 2009/2/EC of 15 January 2009; OJ No. L 11 of 16.01.2009 p. 6

[14] TRGS 905: “List of carcinogenic, mutagenic or toxic-to-reproduction substances“, edition July 2005, BAnz. No. 59a of 24.3.2006 p. 3; GMBl. No. 26 of 4.7.2008 p. 528

[15] Verordnung über Verbote und Beschränkungen des Inverkehrbringens gefährlicher Stoffe, Zubereitungen und Erzeugnisse nach dem Chemikaliengesetz *[Ordinance on prohibitions and restrictions concerning placing on the market of hazardous substances, preparations and articles under the Chemicals Act]* (Chem-VerbotsV - Chemikalien-Verbotsverordnung) of 13 June 2003; BGBl. I of 25.6.2003 p. 867, last amended by Art. 5 (10) of the Ordinance of 26.11.2010 (BGBl. I p. 1643)

[16] Deutsche Forschungsgemeinschaft: "MAK- und BAT-Werte-Liste 2010" *[MAK and BAT values list"]*, Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Wiley-VCH Verlag, Weinheim (2010)

[17] TRGS 554: “Exhaust fumes from diesel engines”, edition October 2008, GMBl. No. 56/58/2008 of 08.12.2008 p. 1179, corr. GMBL No. 28 of 12.5.2009 p. 604

[18] Linsel, G.; Kummer, B.: „Endotoxine in der Luft am Arbeitsplatz“ *["Endotoxins in the air at the workplace"]*, Gefahrstoffe - Reinhaltung der Luft 58, No. 7/8, 281-287 (1998)

[19] Sicherheit und Gesundheit am Arbeitsplatz – IFA Handbuch; Ergänzbare Sammlung *[Safety and health at the workplace – IFA manual, collection which can be supplemented]*, ed.: Berufsgenossenschaftliches Institut für Arbeitssschutz der Deutschen Gesetzlichen Unfallversicherung – IFA, Erich Schmidt Verlag; Code 120120: Cancer risk numbers.

[20] Announcement on Hazardous Substances 910: “Risk values and exposure-risk-relationships in activities involving carcinogenic hazardous substances (Announcement 910)“, edition June 2008, last amended and supplemented: GMBl 2011 No. 10 p. 194

[21] TRGS 505: “Lead”, edition: February 2007, GMBl. No. 12 of 8.3.2007 p. 12

[22] TRBA 214: “Waste treatment installations including sorting installations in the waste management industry”, edition: April 2007, GMBl 2007 No. 35 pp. 709-720

[23] BGR/GUV 190: “Use of respiratory protective equipment“, German Social Accident Insurance (DGUV), status November 2009

[24] DIN EN 345: "Safety footwear for professional use. Specification."

[25] DIN EN 340: "Protective clothing; general requirements", edition March 2004

[26] DIN EN 388 "Protective gloves against mechanical risks". Beuth-Verlag, December 2003

[27] TRGS 500: “Protective measures“, edition January 2008, GMBl. No. 11/12 of 13.3.2008 p. 224; last amended GMBl. No. 26 of 4.7.2008 p. 528

[28] Act on the performance of occupational safety and health measures to improve the safety and health protection of workers at work (Occupational Safety and

Health Act – ArbSchG) of 7 August 1996; BGBl. I 1996 p. 1246, last amended on 05.02.2009, p. 160

[29] TRGS 720 “Hazardous explosive atmosphere – General”; BAnz No. 103a of 2 June 2006

[30] TRGS 721 “Hazardous explosive atmosphere – Assessment of the risk of explosion”; Bundesanzeiger No. 103a of 02.06.2006

[31] TRGS 722: “Avoidance or containment of dangerous explosive atmosphere”; Bundesanzeiger Nr. 103a vom 02.06.2006o

[32] BGI 560: Arbeitssicherheit durch vorbeugenden Brandschutz. (Occupational safety through preventive fire safety) Vereinigung der Metall-Berufsgenossenschaften, 2010

[33] TRGS 401: “Hazard due to skin contact – Identification, assessment, measures“, edition: June 2008; GMBl. No. 40/41 p. 818; last corrected GMBl 2011 No. 9 p. 175

[34] „Staubbelastung bei der werkstofflichen Verwertung von Kunststoffen in hessischen Betrieben“ *["Exposure to particles during the recycling of plastics in facilities in Hesse"]*, Regierungspräsidium Kassel – Fachzentrum für stoffliche und andere Arbeitsplatzfaktoren, October 2003

[35] J. Auffarth, R. Hebisch, A. Johnen, G. Linsel: Stoffbelastungen bei der werkstofflichen Verwertung von Kunststoffen. *[Substance exposures during the material recycling of plastics]* Series of the Federal Institute for Occupational Safety and Health, Gefährliche Arbeitsstoffe (GA 64), Wirtschaftsverlag NW, Bremerhaven (2004)

[36] TRGS 906: “List of carcinogenic activities or procedures according to Article 3 (2) No. 3 GefStoffV“, edition July 2005 (BAnz. No. 59a of 24.3.2006 p. 31; amended GMBl. No. 24 of 27.4.2007 p. 499)

[37] LASI-Veröffentlichung LV 23: "Leitlinien zur Biostoffverordnung" *["Guidelines to the Biological Agents Ordinance"]*, 3rd revised edition, Länderausschuss für Arbeitsschutz und Sicherheitstechnik (LASI) (2008)

[38] Messung von Gefahrstoffen – IFA Arbeitsmappe, Expositionsermittlung bei chemischen und biologischen Einwirkungen: Verfahren zur Bestimmung der Endotoxinkonzentrationen (Kennzahl 9450), der Schimmelpilzkonzentration (Kennzahl 9420), der Bakterienkonzentration (Kennzahl 9430) in der Luft am Arbeitsplatz. Ergänzbare Sammlung *[Measurement of hazardous substances – IFA Folder, Identification of exposure with chemical and biological effects: procedures for determining endotoxin concentrations (code 9450), mould concentration (code 9420) and bacterial concentration (code 9430) in the air at the workplace. Collection that can be supplemented]* published by: Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung – IFA, Erich Schmidt Verlag

[39] Regulation VDI 4253 Sheet 3: Erfassen luftgetragener Mikroorganismen und Viren in der Außenluft - Verfahren zum quantitativen kulturellen Nachweis von Bakterien in der Luft - Verfahren nach Abscheidung in Flüssigkeiten *[Collection of airborne microorganisms and viruses in the outside air – Procedure for the quan-*

titative cultural verification of bacteria in the air – Procedure after separation in liquids], date of issue 08/2008

[40] TRBA 500: “Basic measures to be taken for activities involving biological agents, edition June 1999, BArbBl. 6/99 p. 81

[41] TRGS 907 “List of sensitising substances“ (Announcement of BMA according to Article 52 (3) Hazardous Substances Ordinance), BArbBl 10/2002, pp. 74-76

[42] Ordinance on occupational health care (ArbMedVV) of 18 December 2008, BGBl. I p. 2768, last amended by Article 5 (8) of the Ordinance of 26 November 2010 (BGBl. I p. 1643)

Annex 1: Principles of the assessment of exposures to hazardous substances

Workplace measurements during the material recycling of plastics were conducted by measuring bodies of the federal states of Baden-Württemberg and Hesse [34], the German Social Accident Insurance Institution for the raw materials and chemical industry (BG RCI) and by the Federal Institute for Occupational Safety and Health (BAuA) [8, 35] from 1996 to 2003 in 42 facilities. Within the framework of a reformulation of the present recommendations the data was supplemented to include the results from further measurements in 28 facilities from the years 2002 to 2008 conducted by the measuring body from Baden-Württemberg and from the exposure database MEGA of the Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA).

Annex 2 gives additional information on the exposures to biological agents. These were identified in 51 facilities from 1997 to 2003. On top of this there is more recent data from 23 facilities from the years 2002 to 2008.

In the facilities examined commercial waste, production waste and waste under the Packaging Ordinance and from collections under the Dual System were recycled as material. The majority of facilities supplied a granulate as a product after extrusion, others manufactured sheeting or shaped parts. Some facilities produced ground material or flakes as the end product.

Results of the workplace measurements

During the workplace measurements in the facilities the hazardous substances listed in Table 3 were measured by stationary sampling or personal air sampling. Shift averages and short-time values were obtained. In the summary of the measuring results no distinction was made between the types of plastics recycled.

Table 3 List of substances examined

Substance	Assessment criteria [mg/m^3]	Peak limit	Remarks
Respirable particle fraction(A)	3	2 (II)	TRGS 900 [6]
Inhalable particle fraction (E)	10	2 (II)	TRGS 900 [6]
Diesel particulate matter	-	-	TRGS 906 [36], carcinogenic category 2
Lead	0,1	-	TRGS 505 [21]
Cadmium	Based on cancer risk number	-	Specific workplace risk per 1µg/m³: 0.69-1.97x10^{-3} BGIA 120 cancer risk numbers [19]. From the cancer risk number given according to BekGS 910 [20] it is possible to derive acceptance and tolerance concentrations of 0.2 µg/m³ and 2 µg/m³, respectively.

In the case of the inhalable particle fraction the measuring results were broken down further according to the different process stages. This was necessary since a number of cases arose in the data collective where limit values were exceeded.

Table 4a List of the measuring results for the inhalable particle fraction from the years 1996 to 2003

	Number of facilities	Number of measuring results	Median [mg/m^3]	95 percentile [mg/m^3]	Max. value [mg/m^3]
All measuring results	31	330	0.51	3.62	31.8
of which					
- personal air sampling	29	204	0.54	3.68	31.8
- stationary air sampling	30	126	0.41	3.76	30.6
of which during					
- material feed	16	87	0.53	2.05	3.90
- sorting	13	70	0.44	1.48	2.78
- grinding / shredding	13	49	0.59	6.63	7.21
- washing	4	20	0.33	0.52	0.61
- mixing / compounding	2	11	0.59	31.2	31.8
- granulation / extrusion	12	44	0.49	1.36	3.16
- finishing	8	20	0.37	1.43	1.90
- miscellaneous[2]	14	27	1.18	3.47	4.20

In the detailed examination of the measuring results for individual activities or working areas two values were not considered any further. In one case material was poured into an open container with a dropping height of more than one metre, although there was no extraction facility and the dropping distance was not enveloped by a hose. Under these worst-case conditions the shift average identified with personal air sampling was 11.5 mg/m^3. For the other activities a measurement by personal air sampling resulting in a figure of 29.5 mg/m^3 was not taken into account since here cleaning work had not been properly carried out (blowing and sweeping with major swirling of dust).

With the exception of the activity mixing and compounding the occupational exposure limit is adhered to throughout for the inhalable particle fraction. The readings in excess of the limit value during mixing were obtained at a large-tonnage open mixer which did not have an extractor fitted. Of a total of 11 measurements during mixing figures in excess of the limit value were found in four. Here the process-specific conditions according to 5.1 were not complied with.

[2] In some cases it was not possible to correlate measurements by personal air sampling in particular with individual working stages. This was mainly the case with shift foremen and personnel in charge of the measuring station, who often moved between the different workplaces. Workers also had to change at short notice to other workplaces to help out because the workers there needed assistance. This also includes cleaning and maintenance jobs in the facilities.

Table 4b List of measuring results for the inhalable particle fraction from the years 2002 to 2008

	Number of facilities	Number of measuring results	Median [mg/m³]	95 percentile [mg/m³]	Max. value [mg/m³]
All measuring results	28	53	0.58	4.54	10.7
of which					
- personal air sampling	13	22	1.35	4.76	6.5
- stationary air sampling	19	31	0.36	3.26	10.7
of which during					
- material feed	7	10	0.52	3.15	4.80
- sorting	9	13	0.58	3.06	3.51
- grinding / shredding	7	11	1.70	5.34	6.50
- granulation / extrusion	3	3	1.10	1.87	2.00
- miscellaneous	11	16	0.36	5.36	10.7

The measuring results from the years 2002 to 2008 confirm those from 1996 to 2003. For other activities the occupational exposure limit for the inhalable particle fraction was exceeded once at 10.7 mg/m³. For the activities mixing and compounding no new data was collected.

In the inhalable particle fraction lead and cadmium were determined. The concentrations were a maximum of 0.04 mg/m³ and 0.003 mg/m³ respectively (see Table 5). No short-term higher concentrations were found for either substance. On the basis of the cancer risk numbers given in Table 3 for cadmium, a cancer risk of 8×10^{-4} is obtained for the 95 percentile) (0.4 µg/m³).

Table 5 Concentrations identified during plastic recycling (without inhalable particle fraction) from the years 1996 to 2003

Substance	Number of facilities	Number of measuring results	Median [mg/m³]	95 percentile [mg/m³]	Max. value [mg/m³]
lead	15	125	0.001	0.013	0.037
cadmium	13	99	< 0.000006	0.0004	0.003
respirable particle fraction	37	204	0.19	0.88	2.09
diesel particulate matter					
- shift averages	7	11	0.027	0.045	0.046
- short-time values	5	12	0.14	0.75	0.76

Concentrations due to the respirable particle fraction were below 70 % of the limit value for respirable particles of 3 mg/m³ (see Table 5). In relation to the respective occupa-

tional exposure limit the concentrations due to the inhalable particle fraction for the same activity were higher than that due to the respirable particle fraction.

In some facilities diesel-powered forklifts without particle filters were used in enclosed working areas. Where this was observed measurements were conducted of the carcinogenic diesel particle matter. Short-time values and shift averages were measured here. In the shift average the greatest concentrations were about 0.05 mg/m^3 for elementary carbon (EC). As can be seen from Table 4 there arose for a short time concentrations of up to 0.8 mg/m^3. If forklifts and other industrial trucks with diesel particle filters (DPF) were used no diesel particulate matter (DPM) were measurable.

The exposures of workers during the recycling of plastics are attributable primarily to the particle fractions and their constituents. With the exception of some shift averages for the inhalable particle fraction the measuring results were below the occupational exposure limits throughout.

Concentrations of gases and vapours are of secondary importance. Thus concentrations identified for all solvents were below 2 % of their respective occupational exposure limits. In one facility which recycled plastic containers in contact with oil up to about 90 mg/m³ was identified for the sum of hydrocarbons directly in the installation. These measurements represent the worst case. In practice the workers were never present there for longer than one or two minutes (sum of the presence duration during the shift less than 10 minutes). For all other activities and in all other facilities the concentrations were smaller by at least one order of magnitude.

During the recycling of PVC the hydrogen chloride (HCl) concentrations were measured at the extrusion machines. All concentrations were below 0.08 mg/m^3. During short-term cleaning jobs (< 15 min) concentrations of up to 0.13 mg/m^3 were measured at the extrusion machines. The figures are substantially below the occupational exposure limit of 3 mg/m³ [6].

In Tables 6a and 6b the concentrations identified for hazardous substances are amalgamated for the two periods. Only those substances are listed here which make a significant contribution to the total concentration.

Table 6a Overview of the shift averages identified during the material recycling of plastics from the years 1996 to 2003

Substance	Median [mg/m^3]	95 percentile [mg/m^3]	Max. value [mg/m^3]
Inhalable particle fraction			
all working areas	0.51	3.62	31.8
of which: material feed	0.53	2.05	3.90
sorting	0.44	1.48	2.78
grinding / shredding	0.59	6.63	7.21
washing	0.33	0.52	0.61
mixing /compounding	0.59	31.2	31.8
granulation / extrusion	0.49	1.36	3.16
finishing	0.37	1.43	1.90
miscellaneous	1.18	3.47	4.20
Respirable particle fraction	0.19	0.88	2.09
lead	0.001	0.013	0.037
cadmium	< 0.000006	0.0004	0.003
diesel particulate matter	0.027	0.045	0.046

Table 6b Overview of the shift averages identified during the material recycling of plastics from the years 2002 to 2008

Substance	Median [mg/m^3]	95 percentile [mg/m^3]	Max. value [mg/m^3]
Inhalable particle fraction			
all working areas	0.58	4.54	10.7
of which: material feed	0.52	3.15	4.80
sorting	0.58	3.06	3.51
grinding / shredding	1.70	5.34	6.50
granulation / extrusion	1.1	1.87	2.00
miscellaneous	0.36	5.36	10.7

Annex 2: Information on exposures to biological agents during the material recycling of plastics

Activities involving biological agents are governed by the Biological Agents Ordinance. Biological agents under the Biological Agents Ordinance are in the widest sense micro-organisms which may cause infections and sensitising or toxic effects in humans. To date no Technical Rules for Biological Agents (TRBA) and limit values for biological exposures have been established for the area of the material recycling of plastics.

Below instructions are given concerning the occurrence of biological agents in this area and possible protective measures to be taken within the framework of the risk assessment (LASI-LV 23 [37], TRBA 400 [7]). The present recommendations contain experience gained with comparable activities which has to be considered in the risk assessment in accordance with Article 5 of the Biological Agents Ordinance.

A2.1 Exposures measured for biological agents

The pollution due to airborne biological agents was identified by filter collections and subsequent analysis of the filters. The mould measurements were conducted by the procedure for "Determination of the mould concentration in the air at the workplace", IFA Folder, Code 9420 [38]. For measurements in working areas both the direct method (shorter sampling time and direct application of the impacted filters to culture media) and the indirect method (longer sampling time with subsequent application of a dilution series and plating of the dilution stages on culture media) may be applied. For the evaluation of the mould concentrations in the areas under examination the indirect method has proven to be the suitable method.

To determine the airborne endotoxins the filters were extracted in endotoxin-free water and the endotoxic activity was determined in this extract using the limulus amoebocyte lysate (LAL) test (IFA Folder, Code 9450 [38]).

To verify the pollution due to airborne bacteria the general specifications of the IFA Folder, Code 9430 "Procedure for determining the bacterial concentration in the air at the workplace" [38] was referred to.

On the one hand incubation was conducted at 30 °C, the first counting was performed after 24 hours, and thereafter at 24-hour intervals up to 72 hours, the crucial factor being the highest colony number. On the other hand the total bacteria were verified according to VDI Regulation 4253, Sheet 3 [39]. The plates inoculated are counted visually after 48 hours (incubation at 36 °C) and after seven days (incubation at 22 °C).

Since the database available did not permit an evaluation according to technology stages, the following division according to the plastics recycled was selected:

1. unsorted, biologically contaminated (e.g. normal DSD (Dual System) waste)
2. sorted, biologically contaminated (e.g. pre-sorted PET beverage bottles, composite materials, DSD (Dual System) sheets)
3. cleanly separated, biologically not contaminated (e.g. window profiles, sprue)

The results identified are summarised in Tables 7 and 8.

Table 7a Overview of the measuring results for moulds during the material recycling of plastics from the years 1997 to 2003

Substance group	Number of facilities	Number of measuring results	Median [CFU/m^3]	95 percentile [CFU/m^3]	Max. value [CFU/m^3]
unsorted, biologically contaminated	19	43	6.9×10^5	3.2×10^6	3.6×10^6
sorted, biologically contaminated	17	85	8.9×10^4	1.3×10^6	1.7×10^6
cleanly separated, biologically not contaminated	6	20	8.8×10^3	1.5×10^4	1.5×10^4
unpolluted external air	5	11	2×10^2	1.9×10^3	2.9×10^3

Table 7b Overview of the measuring results for moulds during the material recycling of plastics from the years 2002 to 2008 (unpolluted external air 200 to 700 CFU/m³)

Substance group	Number of facilities	Number of measuring results	Median [CFU/m^3]	95 percentile [CFU/m^3]	Max. value [CFU/m^3]
biologically contaminated, sorted and unsorted	21	144	9.7×10^4	9.9×10^5	2.1×10^6

As expected with unsorted, biologically contaminated material the pollution is the highest at, on average, 6.9×10^5 CFU/m^3. In all, the values identified in these facilities diverge considerably. A range from 0.05×10^6 to 3.6×10^6 CFU/m^3 was identified. The germ concentrations arising are determined in the main by the material throughput quantities, the dustiness of the material (dry, moist, wet), the technical, especially the ventilation and spatial conditions and the state of cleaning of the premises and installations.

If there is sorted, biologically contaminated material, the mould concentration is reduced on average by a power of ten. An average germ pollution is to be assumed.

With cleanly separated, biologically uncontaminated material, such as plastic shaped sections, plastic windows and sheets, moulds were verified in the air, but with an average concentration of 8.8×10^3 CFU/m^3 compared with an external air concentration of 10^2 to 10^3 CFU/m^3 it is hardly necessary to assume a risk.

The more recent results from 2002 to 2008 are in the range of the results for sorted material from the years 1996 to 2003.

Table 8 Overview of the measuring results for endotoxins during the material recycling of plastics

Substance group	Number of facilities	Number of measuring results	Median [EU/m^3]	95 percentile [EU/m^3]	Max. value [EU/m^3]
unsorted, biologically contaminated	1	8	26.5	82	83
sorted, biologically contaminated	5	44	32.6	395	928
cleanly separated, biologically not contaminated	4	22	1.7	10.8	16.7
unpolluted external air	8	12	0.1	0.4	0.5

Endotoxins reflect a concentration of gram-negative bacteria and showed a maximum concentration of 1000 EU/m³. They are significantly higher during the processing of biologically contaminated material as compared to the reference external air. It was not possible to demonstrate with the data available an effect from the pre-sorting of the material being recycled. In all it is necessary to assume a rather low risk from endotoxins in the recycling facilities examined.

The bacterial concentration was identified over ten measurements in five different facilities. With an incubation temperature of 30 °C the measuring results were between 1.4 x 10^3 and 1.8 x 10^4 CFU/m^3. At 22 °C results from 1.0 x 10^2 to 1.0 x 10^4 CFU/m³ were measured, at 36 °C results from 1.5 x 10^2 to 6.0 x 10^3 CFU/m^3. In the external air the measuring results were between 1.0 x 10^2 and 3.0 x 10^2 CFU/m^3 (Note: In view of the low bacterial concentrations such measurements are only conducted in the facilities if there is a justified suspicion).

In all it is not possible to draw detailed conclusions for individual technology stages from the measuring results available because of different technologies and installations.

A2.2 Protective measures with respect to biological agents

In the processing of biologically contaminated plastics biological concentration must be expected regardless of pre-sorting. Biological concentrations are to be expected if the following arise:

- moistly stored material is being recycled which can serve as a nutrient medium (e.g. composite paper and paperboard material),
- food residues, faeces or aqueous used cooling lubricants.

At permanent workplaces (activity lasting more than 2 hours in a shift) the concentrations of biological agents must be minimised. All measures mentioned under 5.1 for the reduction of hazardous substances also contribute to a reduction in the concentration of biological agents.

The more the biologically contaminated material is moved mechanically and separated out, the greater the release of germs and hence of the air pollution. If the manual sorting

of sorted or unsorted biologically contaminated plastic material cannot be avoided, the following measures must be taken:

- sorting in a special sorting booth, spatially separate from the rest of the hall area,
- use of an effective ventilation system.

If biological agents are being handled at workplaces the minimum standards of TRBA 500 [40] must be complied with.

Occupational health care

Mould-bearing particulates are classified in TRGS 907 [41] as sensitising. The sensitising effect must be the subject of special attention within the framework of occupational medical consultations for workers who perform activities involving biological agents in accordance with Article 12 (2a) BioStoffV [2], with the involvement of a physician according to Article 7 (1) of the Ordinance on Occupational Health Care (ArbMedVV) [42]. During the consultations the workers must be informed about the voluntary examinations offered under ArbMedVV.