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BG/BIA-Recommendations for Monitoring of Work Areas

Manual Disassembly of Monitors and Other Electrical Equipment
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1 Area of Application

The criteria for maintaining limit values are established in the present BG/BIA Recommendations[*)], under which control measurements can be replaced by control measures in certain disassembly work of monitors and other electrical equipment of educational and household electronics, data processing and office equipment and their corresponding assemblies.

During disassembly work according to these BG/BIA Recommendations, work in which

- monitors (for example, televisions, computer monitors, oscillographs and similar) and other electronic equipment (for example, telephones, computers, vacuum cleaners, educational electronics) are prepared and disassembled using tools
- tubes are vented
- pollutant-containing components are removed

is involved.

These BG/BIA Recommendations do not apply for work areas, in which

- equipment is disassembled, in which special hazards, for example, chemical, biological or radioactive in nature, can occur. This can be the case in equipment used, for example, in the chemical industry, medicine, semiconductor production in galvanic installations or nuclear installations
- fluorescent tubes are disassembled
- cathode ray tubes are disassembled and the phosphor layer is removed
- equipment containing asbestos-containing products is disassembled
- equipment from emergencies (for example, fire damage) is disassembled
- larger devices of household appliances (for example, refrigerators, washing machines, stoves) is disassembled
- complete equipment or materials recovered from electrical and electronic equipment to the raw material level is further processed (for example, shredders).

2 Work Method/Activity

Each year, about 2 million tonnes of electrical and electronic scrap with about 5 million cathode ray tubes occurs in the Federal Republic of Germany. Manufacturers and marketers of electronic equipment are subject to the recycling requirement with entry into force of the Recycling Economy and Waste Law (KrW-/AbfG [1]). Older equipment is

[*)] The contents of these BG/BIA Recommendations are identical to the LASI-ALMA Recommendations LV 27.

disassembled and separated into valuable material fractions, in order to comply with this recycling requirement. The disassembly process of the delivered material is generally broken down into the following steps:

- Preparation
- Coarse preliminary sorting of the delivered material
- Cleaning of the material (for example, in closed cleaning cabins)
- Venting of the cathode ray tubes (for example, in closed cleaning cabins)
- Manual disassembly and separation into individual fractions (for example, into assemblies, like housing, circuit boards, cathode ray tube, control electronics) with subsequent further disassembly of the assemblies
- Removal of components containing hazardous substances (for example, capacitors, batteries, storage batteries, displays or mercury-containing switches)
- storage and disposal of the different fractions.

3 Exposure to Hazardous Substances

The dust deposited in the interior of the equipment during its operating time, which can be released on opening of the equipment and subsequent disassembly, can be loaded with hazardous substances. Moreover, hazardous substances can be absorbed on contact with contaminated equipment. Monitors with broken cathode ray tubes (cadmium-containing phosphor layer), hazardous capacitors (PCB) or mercury-containing switches are mentioned here, in particular. When slightly or not very loaded equipment is stored and transported together with strongly contaminated equipment or equipment containing defective components, there is a hazard that this equipment is also contaminated.

During work on equipment, absorption of hazardous substances via the skin, respiratory tract and mouth can therefore occur (dermal, inhalation and oral absorption). In principle, it must be kept in mind that even when the air limit value is maintained, there can be a residual health risk in substances with a TRK value.

3.1 Hazardous Substances

A number of different hazardous substances can be released in cleaning/disassembly workplaces (see Table 1 in the appendix). The occurrence and hazard potential of selected substances are described below.

- Azobenzenes can be contained in LC displays. Some azobenzenes and other azo compounds are classified as carcinogenic in humans. An inhalative load is unlikely. Skin contact, however, must be avoided.
- Beryllium is found as an alloy component, among other things (for example, in collectors and mechanical components) and in x-ray technology. Beryllium can have a sensitizing effect, produces granulomatous skin changes and, like its compounds, is carcinogenic.

- Lead is a component of the cathode ray tube glass (neck and cone glass) and is used in the form of glass solder to join the front and cone glass. It is also contained in soft solder. Lead compounds have a fetal-damaging effect in humans (development-impairing) and might adversely affect reproductive capability of humans. During maintenance of the air limit value, fetal damage cannot be ruled out during exposure of pregnant women. Lead compounds can be enriched in the body and have a special effect on it in so doing.
- Cadmium is found in batteries, soft solder, circuit boards and in the form of cadmium sulfide in the phosphor layer, which is applied to the inside of the front glass of the cathode ray tube. Cadmium and its compounds are carcinogenic and toxic when inhaled and swallowed. Cadmium compounds can be enriched in the body and have a special effect on it in so doing.
- Cobalt can be present in dyes and paints. Cobalt can have a sensitizing effect and, like its compounds, is carcinogenic.
- Nickel occurs in circuit boards, thermocouples, batteries and in hole masks of cathode ray tubes. Nickel can have a sensitizing effect and, like its compounds, is carcinogenic.
- Polychlorinated biphenyls (PCBs) can be contained in capacitors. They are a health hazard and possibly carcinogenic. They are also absorbed via the skin. PCBs have a fetal-damaging effect in humans (developmental impairment) and might adversely affect reproductive capability in humans. Even when the air limit value is maintained, fetal damage cannot be ruled out during exposure of pregnant women. PCBs can be enriched in the body and, in so doing, have a special effect on it.
- Mercury can be contained in switches and fluorescent tubes and is toxic when inhaled. Mercury can be enriched in the body and have a special effect on it in so doing.
- Yttrium can be contained in the phosphor layer of cathode ray tubes. Yttrium compounds have an irritating effect on the eyes and lungs.
- Dust that contains no hazardous substances as ingredients can be released during disassembly of equipment. Nonspecific effects on respiratory organs must be considered.

3.2 Evaluation of Hazardous Substance Exposure

Extensive measurements in numerous plants have been conducted by industrial societies, the State Office for Environmental Protection of Baden-Württemberg, the Central Office for Industrial Health and Safety Kassel in the Hessian State Office for the Environment and Geology and the Federal Institute for Industrial Health and Safety and Occupational Medicine.

Evaluation of the available dataset showed that of the number of hazardous substances occurring in the air in the workplace, cadmium and lead, in particular, can make a relevant

contribution to exposure. Mercury is significant, if corresponding mercury-containing effective components occur in the workplace.

The level of exposure can be influenced by different parameters (including age and degree of contamination of the equipment, equipment throughput at the workplace, type and configuration of protective equipment, individual work methods). This heterogeneity makes it difficult to reliably prove statistically the significance of individual factors on the level of measured hazardous substance concentrations in air. Evaluation shows, however, that an overall lower exposure level (with limit value maintenance for the target parameters cadmium and lead) is observed during preliminary cleaning of monitor equipment in closed cleaning cabins.

Separate metrological determination of process-related exposure peaks according to TRGS 402 [2] was dispensed with in operational measurements, since these are dependent on the different already mentioned variables with respect to their intensity and frequency and cannot be repeated reproducibly. The occurrence of exposure peaks during venting of cathode ray tubes is prevented by using a closed cleaning cabinet.

Under the condition the release of dust or mercury vapors is avoided by proper work techniques in the corresponding work organization and components containing hazardous substances are disassembled properly, it is possible to comply with the air limit values for cadmium, lead and mercury and the evaluation index according to TRGS 403 [3]. Control measurements can be dispensed with, when the recommendations mentioned in Chapter 4 are applied.

4 Measures

The technical, organizational, hygienic and personal protective measures described below for disassembly of cathode ray tubes and other electrical equipment allow one to expect compliance with the limit value for the relevant hazardous substances that occur, suppression of skin contact and avoidance of oral absorption. In principle, the general occupational hygiene principles described in TRGS 500 [4] are to be observed.

Technical Protective Measures

- Cathode ray tubes, as well as electrical equipment, which is contaminated by joint storage with monitor equipment, broken cathode ray tubes, must be cleaned in a closed cleaning cabinet from dust on the outside and inside by means of compressed air.
- Venting of the cathode ray tubes occurs in the cleaning cabin. Before venting of the cathode ray tube, it must be discharged with a high-resistance (> 1 MΩ) resistor from residual voltage [5].
- The cleaning cabin must be integrated in the work process.

- In order for work surfaces (tables) to be easy to clean, they should be provided with a smooth surface and a continuous edge.
- The floors of the work area must be configured, so that released materials can be recognized and completely eliminated (for example, mercury). The floor must also be easy to clean.

Technical Specifications of the Cleaning Cabin

- The closed cleaning cabin must be connected to an exhaust line. The escape of dusts loaded with hazardous substances during the cleaning process must be prevented.
- Suction of the blown-out dust form the cleaning cabin must have a sufficiently powerful suction device with appropriate filter and be used in force air operation. The power of the suction device is sufficient, if a 300-fold air change per hour is guaranteed in the cleaning cabin. For reasons of energy saving, the suction device should only be operated during cleaning and with a corresponding final operating time (at least 30 seconds).
- If air return (circulating operation) cannot be avoided, the requirements of TRGS 560 [6] must be observed. Suction equipment of category H is to be used according to this.
- For blow-out of the deposited dust, compressed air should be used. During use of a compressed air gun, its handling generally occurs via corresponding engagement openings in the cabin (use of turn-up sleeves lying against the arm to avoid skin contact).
- Compressed air locking must exist, which permits operation of compressed air only with the closed cabin and guarantees a sufficient final running after compressed air use (2-3-fold air change).
- The cabin must guarantee mechanical splattering protection.

Organizational Protective Measures

Delivery/Storage

- A written agreement concerning the following points is to be made with suppliers of scrap equipment according to a preventive work and health protection:
  - Collection and depositing of equipment in corresponding containers must occur as mildly as possible, i.e., free of destruction.
  - Contamination of equipment by hazardous substances from other defective equipment is also to be avoided by corresponding intermediate storage protected from weather (for example, covering or enclosure of the containers).
  - Separation collection and storage of monitors and other electrical equipment is desirable.
- Components that potentially emit hazardous substances (for example, capacitors, mercury switches), which are deposited in open collection vessels at the workplace, are to be regularly disposed of (at least every 2 hours) in closable storage vessels. The opening cross-sections of the collection containers are to be configured as small

as possible, for example, by means of rubber sleeves. The collection vessels are to be marked.

– Storage of components that potentially emit hazardous substances and fractions should occur outside the work area exclusively in closed and marked containers.
– For handling of electronic scrap that is not prescribed for disassembly (for example, cathode ray tubes, wet-cell batteries), corresponding protective measures and storage conditions are to be established.

Disassembly Work

Because of the hazard of release of hazardous substances by disassembly of components or swirling of still adhering dust, the equipment must be disassembled as free of destruction as possible, especially

- hammers are only to be used as a disassembly tool when disassembly in another way is not possible,
- electric screwdrivers instead of pneumatically operated screwdrivers are to be used and
- the equipment must not be thrown, but set down.

– The functional capability of venting equipment belonging to the cleaning cabin must be checked daily before starting work (testing, for example, with a flow tester).

Cleaning

– The workplaces and work areas are to be cleaned regularly with a low-dust method. Workplaces, like tables or floors, are to be cleaned at least once a day with an industrial vacuum cleaner of category H [7], large shop floors with appropriate suction machines.

Other Measures

– Activity-related operating instructions are to be prepared in understandable form according to TRGS 555 [8].
– An operating instruction for maintenance, regular changing and disposal of filters of the cleaning cabin and suction equipment are to be prepared.
– The employees must be instructed regularly by means of operating instructions with respect to handling of hazardous substances at least once a year. Recognition of components loaded with hazardous substances in scrap equipment (for example, mercury-containing switches, PCB-containing capacitors) and the proper handling must also be taken up (qualification of employees).
– Measures are to be established that prevent a health hazard on escape of hazardous substances, for example, by blocking off/marking the accident location, application of appropriate absorbers, for example, zinc dust from mercury, in sufficient amounts, proper disposal and personal hygiene.

Suction equipment is to be checked at yearly intervals according to § 53 of the Workplace Ordinance and according to Section 5.9 of TRGS 560 [6]. According to the "Rules for Safety and Health Protection in Workplaces with Workplace Ventilation" [9], ventilation equipment must be checked at least every two years by an expert. The result of the test must be documented. Ventilation equipment must be checked daily before starting work for functional capability.

- The introduction of hazardous substances from other work areas, also by industrial trucks, is to be avoided, for example, by spatial separation of work areas.
- Appropriate hoisting and transport aids must be used.
- All work processes must be established in writing.

Hygiene and Personal Protective Measures

- A strict ban against smoking, use of snuff, eating and drinking must be maintained at workplaces, in order to avoid oral absorption of hazardous substances.
- Work clothing is to be worn. This must guarantee necessary protection against skin contact with the working substances to a sufficient degree (see also BGR 189 [10]).
- According to § 22 of the Hazardous Substances Ordinance, washrooms and rooms with separate storage capabilities for street and work clothing must be made available. The work clothing must be cleaned and kept in stock by the company.
- Breaks should be taken, if possible, without work clothing (for example, protective smock) in separate rooms.
- Appropriate sanitary and social facilities must be available.
- During handling of filters of the cleaning cabin, personal protective equipment must be worn.
- Protective goggles must be worn, when there is a hazard of injury from fragments.
- During disassembly work with a hazard of incision, incision-proof gloves must be worn. During handling of components that contain skin-resorptive substances, tested and certified nitrile- or PVC-coated gloves with the EC mark must be used.
- Effective skin-protective measures must be taken according to the industrial "Rules for Use of Skin Protection" [11].

5 Application Instructions

Because of the carcinogenic effect of cadmium and the damaging effect on the fetus of lead, expectant mothers, according to § 5, paragraph 1 of the Ordinance on Protection of Mothers in the Workplace [12], may not be employed in these workplaces.

To evaluate the health relevance from hazardous substances (internal load), it is recommended according to TRGS 710 [13] to enable the employees to participate in biomonitoring. The need for biomonitoring results for handling of

carcinogenic and mutagenic substances, as well as substances that can be absorbed via the skin. The oral route of absorption can also be significant in the presence of negligent hygiene in the workplace.

The user of these BG/BIA Recommendations must check the validity of the requirements during process changes and otherwise regularly, but at least once a year, and document the result. This includes checking of the unchanged validity of these BG/BIA Recommendations. Checking can occur in the context of hazard evaluation according to § 5 of the Industrial Health and Safety Law.

These BG/BIA Recommendations provide employees with practical instructions on how to comply with the monitoring obligation according to § 18 of the Hazardous Substance Ordinance. During application of these BG/BIA Recommendations, other requirements of the hazardous substance ordinance, especially the reporting obligation (§ 16 of the Hazardous Substances Ordinance), parts of the monitoring obligation according to § 18 of the Hazardous Substances Ordinance (for example, overall evaluation of exposure during alternating activities of the employees within a shift or during different activities with different hazardous substances in different work areas), the obligation to observe the sequence of protective measures (§ 19 of the Hazardous Substances Ordinance) and the obligation to prepare operating instructions and regular training of employees (§ 20 of the Hazardous Substances Ordinance), continue in force.

6 Checking

These BG/BIA Recommendations were issued in October 2001. They are checked at annual intervals. If changes become necessary, especially with respect to any limit value reductions, these will be published.

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[10] Industrial Rules for Safety and Health at Work: Use of Protective Clothing (BGR 189, previously ZH 1/700). Carl Heymanns, Cologne 1994

[11] Industrial Rules for Safety and Health at Work: Use of Skin Protection (BGR 197, previously ZH 1/708). Carl Heymanns, Cologne 2001

[12] Ordinance for Protection of Mothers in the Workplace (Mother Protection Guideline Ordinance). BGBl. 1 (1997), No. 23, page 782

[13] Technical Rules for Hazardous Substances: Biomonitoring (TRGS 710). BArbBl (2000) No. 2, pages 60-62, on the Internet at www.baua.de/prax

Appendix

Hazardous substance loading during manual disassembly of monitors and other electrical equipment

1 Hazardous substances/Limit values

Table 1: Air limit values of considered hazardous substances [1] (Status: September 2001)

Hazardous substance	Air limit value		Violation factor	Classification
	mL/m^3	mg/m^3		
Beryllium		0.002 E	4	K 2; S
Lead compounds		0.1 E	4	R_E 1; R_F 3
Cadmium and its compounds		0.015 E	4	K 2
Chlorinated biphenyls (42% chlorine)	0.1	1	4	K 3; R_E 2; R_F 2; H
Chlorinated biphenyls (54% chlorine)	0.05	0.5	4	K 3; R_E 2; R_F 2; H
Chromium(IV) compounds		0.05 E	4	K 2; S
Cobalt bioavailable		0.1 E	4	K 3; S
Copper and its compounds		1 E	4	
Manganese		0.5 E	4	
Nickel		0.5 E	4	K 3; S
Mercury	0.01	0.1	4	
Yttrium and its compounds		5.0 E	4	
General dust limit value			4	
A – Dust fraction		3.0		
E – Dust fraction		10*)		
Fiber dusts, inorganic	250,000 F/m^3			see TRGS 905

E: Inhalable fraction

A: Alveolar-permeable fraction

R_E: Fetal-damaging (development-impairing)

R_F: Adverse effect on reproductive capacity (fertility)

K 2: Substances that should be considered carcinogenic in humans

K 3: Substances that cause reason for concern, because of possible carcinogenic effect in humans

H: Skin-resorptive substances

S: Sensitizing substances

*) Valid as of 4/1/2004, but must already be considered in hazard evaluation.

2 Hazard substance exposure measurements

Extensive measurements were conducted in numerous plants by the professional trade associations, the State Institute for Environmental Protection Baden-Württemberg, the Central Office for Industrial Health and Safety Kassel in the Hessian State Office for the Environment and Geology and the Federal Institute for Industrial Health and Safety and Occupational Medicine.

The plants in which measurements were conducted showed significant differences with respect to equipment layout. In smaller plants, the equipment, especially monitors, is mostly disassembled manually. In large operations, there are semi-automatic disassembly lines, with which up to 300 monitors/shift can be vented and disassembled. The throughput of monitor equipment can vary in different plants by a factor of 50.

Whereas the cathode ray tubes are only vented in some plants, other plants break them down into additional fractions (for example, front and cone glass), and then also remove the phosphor layer. During suction of the phosphor layer from cathode ray tubes, very high limit value violations for cadmium (up to 140 $\mu g/m^3$) were repeatedly observed. Since this activity does not belong to the area of application of the present BG/BIA Recommendations, all measurements in this respect are not considered here.

As evaluation of the present dataset has shown, avoidance of dust exposure in the disassembly workplaces is assigned central significance. This can be achieved most effectively by precleaning of the monitor equipment in a cleaning cabin connected to an exhaust line. In the following presentation of the measurement results, a distinction is made between plants that already have integrated precleaning in the process and those, who have still not introduced it.

2.1 Exposure measurements in plants with closed cleaning cabins

2.1.1 Manual disassembly of monitors and other electrical equipment

In the context of the professional trade association Special Measurement Program “Electronic Scrap Recycling” (see Table 2), measurements were conducted in plants that have already implemented some of the measures mentioned in Chapter 4; in particular, closed cleaning cabins were used here. The equipment throughput was between one and 18 devices per hour. Limit value violations were not found.

Table 2: Shift averages during disassembly of monitors and other electronic equipment in plants with cleaning cabins (BG Special Program)

Hazardous substance	Number of measurement data	Number of Plants	50% value (mg/m^3)	95% value*) (mg/m^3)
A-dust fraction	5	2		
E-dust fraction	29	4	0.36	1.96
Beryllium	19	4	0.0003	0.0004
Lead	28	4	0.001	0.01
Cadmium	28	4	0.0002	0.0036
Chromium (total chromium)	10	1	0.00020	0.0013
Copper	10	1	0.0004	0.0016
Mercury	3	2		
Nickel	10	1	0.0002	0.0008
Yttrium	18	3	0.004	0.01

*) 95 percentile means that 95% of the determined measurement results were below the numerical value mentioned in the table.

On commission of the Federal Institute for Industrial Health and Safety and Occupational Medicine (BAuA), ten person-worn and nine stationary samplings were conducted by the Laboratory for Environmental Engineering of the Iserlohn Technical University (MFH) in two plants with cleaning cabins (12 and 15 employees). In both plants, comparatively low loads were found in the disassembly areas beforehand (see Table 3). Limit value violations were not found.

Table 3. Shift averages during disassembly of electronic scrap in plants with cleaning cabins and evaluation index for the substance mixture (BAuA/MFH)

Hazardous substance	Number of measurement data	Number of Plants	50% value (mg/m^3)	95% value*) (mg/m^3)
A-dust fraction	8	2	0.03	0.12
E-dust fraction	24	2	0.935	3.64
Lead	24	2	0.002	0.0089
Cobalt	24	2	< NWG	0.01
Manganese	24	2	0.001	0.003
Nickel	24	2	0.001	0.01
Cadmium	24	2	0.0004	0.0023

*) 95 percentile means that 95% of the determined measurement results were below the numerical value mentioned in the table.

The evaluation index I, as the sum of substance indices (concentration/air limit value) over all individual measurement results, was at 0.09 for substances with an MAC value, at 0.21 for substances with a TRK value (limit value = 1).

2.1.2 Dust removal from monitors/Venting of cathode ray tubes in the cleaning cabin

In the aforementioned plants, the Iserlohn Technical University (BAuA/MFH) conducted four person-worn and six stationary samplings in the work step "Dust removal from equipment and venting of cathode ray tubes" in the cleaning cabins. The measurement results show an overall low load level (see Table 4). Limit value violations were not observed.

Table 4: Shift averages for activities in the cleaning cabin and evaluation index for the substance mixture (BAuA/MFH)

Hazardous substance	Number of measurement data	Number of Plants	50% value (mg/m^3)	95% value*) (mg/m^3)
A-dust fraction	2	2	< NWG	< NWG
E-dust fraction	10	2	0.605	1.24
Lead	10	2	0.001	0.003
Cobalt	10	2	< NWG	0.011
Manganese	10	2	< NWG	< NWG
Nickel	10	2	< NWG	0.0025
Cadmium	10	2	0.003	0.0006

*) 95 percentile means that 95% of the determined measurement results were below the numerical value mentioned in the table.

The evaluation index I, as the sum of substance indices (concentration/air limit value) over all individual measurement results, was at 0.14 for substances with an MAC value, at 0.04 for substances with a TRK value (limit value = 1).

During dust removal from monitors in plants with cleaning cabins, measurements were also conducted by the professional trade associations (see Table 5).

Table 5: Shift averages for activities in the cleaning cabin

Hazardous substance	Number of measurements	Number of plants	Shift average (mg/m^3)
A-dust fraction	1	1	< 0.16
E-dust fraction	5	3	0.22-1.21
Beryllium	5	3	< 0.00017 – 0.0007
Lead	5	3	< 0.001 – 0.0029
Cadmium	5	3	< 0.0002 – 0.005
Fiber dust	2	2	60,000 – 100,000 general*)
Nickel	1	1	0.00013
Mercury	3	3	< 0.002
Yttrium	5	3	0.00016 - < 0.02

*) In fibers/m^3.

2.2 Exposure measurements in plants without closed cleaning cabins

In the context of the professional trade association Special Measurement Program "Electronic Scrap Recycling", measurements were also conducted in plants that use no closed cleaning cabins. The measurement results of the stationary and person-worn samples during manual disassembly of electronic scrap in these plants are shown in Table 6. They show that the limit values of most substances (for example, copper, nickel, yttrium, general dust limit value) are maintained. However, with cadmium and mercury, a limit value violation was observed in one case each.

Table 6: Shift averages during disassembly of monitors and other electronic equipment in plants without cleaning cabins (BG Special Program)

Hazardous substance	Number of measurement data	Number of Plants	50% value (mg/m^3)	95% value*) (mg/m^3)
A-dust fraction	26	14	0.25	0.94
E-dust fraction	28	13	1.55	4.99
Barium*)	23	11	0.02	0.07
Beryllium	20	9	0.0001	0.0005
Lead	29	15	0.005	0.03
Cadmium	30	15	0.0009	0.0075

*) Barium, insoluble compounds: no limit value.

The Iserlohn Technical University (BAuA/MFH) determined the load situation of the employees (4 to 18 employees) during manual disassembly of electronic scrap in plants without cleaning cabins. Limit value violations for cadmium, lead and inhalable dust fraction (valid from 4/1/2004) were determined in the work areas, in which monitors were disassembled (see Table 7) [2].

Table 7: Shift averages during disassembly of electronic scrap (without household appliances) and evaluation index for substance mixture (BAuA/MFH)

Hazardous substance	Number of measurement data	Number of Plants	50% value (mg/m^3)	95% value*) (mg/m^3)
A-dust fraction	30	7	0.11	0.9
E-dust fraction	89	8	1.48	14.8
Lead	89	8	0.007	0.061
Cobalt	87	8	< NWG	0.007
Manganese	89	8	0.001	0.014
Nickel	87	8	< NWG	0.005
Cadmium	89	8	0.0015	0.055

*) 95 percentile means that 95% of the determined measurement results were below the numerical value mentioned in the table.

The evaluation index I, as the sum of substance indices (concentration/air limit value) over all individual measurement results, was at 0.64 for substances with an MAC value, at 3.69 for substances with a TRK value (limit value = 1).

The Central Office for Industrial Health and Safety (ZfA), Kassel, investigated loading with lead, cadmium and inhalable dust fraction in the area of disassembly of monitors in six plants without room ventilation equipment with 5 to 150 employees with 64 samples (person-worn and fixed) (see Tables 8a and 8b). In two of the six plants, the monitors were cleaned after venting of the cathode ray tubes in a closed cabin with compressed air. In four of the plants, the work areas were cleaned with brooms. The daily throughput of the vented cathode ray tubes in the plants was between 40 and 325.

Table 8a: Shift averages during disassembly of monitors and other electronic equipment in plants with a cleaning cabin (ZfA)

Hazardous substance	Number of measured values and shift averages (in parentheses)	Number of plants	Shift average (mg/m^3)
E-dust fraction	9 (2)	2	0.4/0.6
Cadmium	14 (5)	2	0.0005 – 0.005 *)
Lead	14 (5)	2	< 0.001 – 0.01

*) In one plant, an average of 0.124 mg cadmium/m^3 was measured in the area of rough disassembly during a double-determination. A cause for emission could not be clearly identified.

Table 8b: Shift averages during disassembly of monitors and other electronic equipment in plants without a cleaning cabin (ZfA)

Hazardous substance	Number of measured values and shift averages (in parentheses)	Number of plants	Shift average (mg/m^3)
E-dust fraction	8 (3)	4	0.2 / 0.5 / 1.6
Cadmium	26 (10)	4	0.0002 – 0.003
Lead	26 (10)	4	< 0.003 – 0.02

The State Institute for Environmental Protection Baden-Württemberg (LfU), Karlsruhe, conducted measurements for dust (inhalable and alveolar-permeable fraction), heavy metals, fibers, VOC and PCBs in five small plants, in which no cleaning cabins were used. Table 9 shows an overview of the important results [3].

- All dust measurements gave values below the now valid or discussed limit values.
- In addition to the heavy metals listed in Table 9, 20 additional ones were measured, but their amounts were negligible relative to total load. Only cadmium, lead and mercury were significant among the heavy metals.
- The directly measured mercury concentration in the workplaces was generally below 0.01 mg/m^3, at one workplace, however, it was above the limit value at 0.21 mg/m^3.
- In the inorganic fibers, the measured value was below the determination limit of 4200 $Fm/^3$ in 15 of 18 cases. Asbestos fibers were not found in any case.

- The solvent load (volatile and medium-volatile organic solvents) was generally in the range of normal outside air load in the plants, the evaluation index was always less than 0.1.
- Of the PCBs, only individual congeners could be detected in traces. The total contribution of PCB to the evaluation index I_{MAC} according to TRGS 403 was < 0.1 in all plants.

Table 9: Shift averages during disassembly of monitors and other electronic equipment (LfU)

Hazardous substance	Number of measurements	Number of plants	Shift average (mg/m^3)
A-dust fraction	10	5	< 0.5
E-dust fraction	55 (31 persons, 24 fixed)	5	0.46 – 5.3, < 0.5 – 2.1
Lead	55	5	< 0.001 – 0.023
Cadmium	55	5	< 0.001 – 0.005
Chromium	55	5	< 0.001 – 0.003
Mercury	directly indicating	5	< 0.005 – 0.21
Fibers	18	5	< 4200 – 27600 F/m^3
PCB	15	5	< 0.05

References

[1] Technical Rules for Hazardous Substances: Evaluation of Substance Mixtures in Air in the Workplace (TRGS 403). BarbBl. 10, pages 71-72
on the Internet at www.baua.de/prax

[2] Hanke, M.; Ihrig, Ch., ; Ihrig, D. F.: Substance Load in Electronic Scrap Recycling. Document series of the Federal Institute for Industrial Health and Safety and Occupational Medicine – Hazardous Work Substances – GA 56. Wirtschaftsverlag NW, Bremerhaven 2001.

[3] Industrial Health and Safety During Recycling of Electrical and Electronic Scrap, Project Report No. 34-5534.4-17/97.1001. State Institute for Environmental Protection Baden-Württemberg, Karlsruhe 1999