3. Notes on the analysis and evaluation of environmental impacts

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Emissions produced by the iron and steel industry require particularly extensive measures and systems for **air protection**. Above all, **dusts** containing substances hazardous to health and the environment, such as lead, cadmium, mercury, arsenic and thallium, must be cleaned by high-performance separation systems. Nowadays, not only the primary emission sources, such as sintering plants, but also secondary sources such as blast furnace casting bays can be intercepted and dedusted. In the case of **gaseous emissions**, attention must be paid primarily to reducing carbon monoxide and sulphur dioxide, as well as nitrous oxides and fluorine compounds.

Monitoring of permissible emissions and the **effectiveness** of waste gas cleaning systems must be guaranteed by **measurements**. The dust must also be periodically analysed to detect heavy metals. Emissions must be measured after commissioning the plant to see whether the values assumed in the planning correspond to the reality. If there are discrepancies, new forecasts must be made and **further reduction measures** implemented if necessary.

Emission and immission standards applicable in Germany are detailed in TA-Luft (Technical

Instructions on Air Quality Control) and in the Grofeuerungsanlagenverordnung (Ordinance on Large Firing Installations). In the USA, guidelines and standards for the iron and steel industry have been published by the Environmental Protection Agency.

The guidelines adopted by the Association of German Engineers (VDI) contain detailed descriptions for performing emission and immission measurements. Measuring equipment designed for continuous operation must be rigorously examined for robustness, error detection ability and ease of maintenance. Maintenance contracts should be concluded with suppliers. Continuously operating measuring instruments should be employed for measuring dust, sulphur dioxide, fluorine compounds and nitrous oxides (e.g. in the sintering plant and the steel works).

Recycling of water and **the use of closed-circuit cooling water systems** deliver cost-savings and a high rate of re-use in iron and steel works. **Effective water treatment systems** are needed for this purpose.

General **minimum requirements** are laid down in Germany for treated **wastewater** discharged into receiving bodies of water and for special plants. These parameters must be monitored by measuring equipment at the point of transfer of the cleaned water to the receiving body of water. **Cleaning systems for waste gases and water** can only satisfy their intended purpose when they are **correctly operated, serviced and repaired**. The provision of detailed operating, maintenance and repair manuals is imperative.

Practically all processes involve greater or lesser levels of noise. High noise emissions can cause annoyance in the vicinity if reduction and protection measures are inadequate. In Germany, TA-Lrm (Technical Instructions on Noise Abatement) and the guidelines adopted by the Association of German Engineers (VDI) are used for calculating and assessing noise immissions in the **neighbourhood**. Noise immissions are assessed against immission reference values which are graded according to the type of area to be protected and the periods of noise. Guidelines are also available for assessing noise emissions at the workplace.

As in Germany, **works environmental protection officers** should be deployed in iron and steel works who are totally independent of the production side. Their task is essentially to work towards the development and introduction of **environment-friendly processes**. In addition they are entitled and obliged to monitor **adherence to statutory regulations** and **compliance with official directives and conditions** in so far as these relate to environmental protection.

The scope and monitoring of **working conditions and health protection measures**, which vary from one workplace to another, should be set down in a manual. Proposals are detailed in the regulations of the **employers' liability insurance association (Berufsgenossenschaft**) **of the iron & steel industry**. Suitably qualified **safety officers** and a **works doctor** should be appointed.

4. Interactions with other sectors

The erecting of iron and steel production plants involves **land-use** which is measured in terms of the works site with adjoining areas and connecting roads. Before erecting production plants, impacts on the local natural order and the geogenic and anthropogenic burdens on the soil and groundwater and on any bodies of surface water must be investigated in the context of the **location planning**. An adequate distance from the nearest residential zones must also be guaranteed. Details are contained in the environmental brief Planning of Locations for Trade & Industry.

Iron and steel works involve large-scale production and require large amounts of **raw materials**. These include primarily ores, coke and limestone. Generally speaking, to produce 1 tonne of crude steel requires 450 to 500 kg coke and fuel oil, 250 kg lime and 5 m^3 water.

In an integrated iron works for example, the specific **total energy consumption** is some 20 GJ/t crude steel. In an integrated iron works, the sintering plant, blast furnace, coking plant, steel works, rolling mill and power station areas are interconnected as a **combined energy system**. Thus, the top gas is utilised in all areas, its calorific value enriched with converter gas, coking oven gas or natural gas. Power and steam are supplied by the power station. Boilers are usually operated with gas, e.g. top gas. The burners can be fired with top gas, coking oven gas or fuel oil. **External power supplies** are used in addition to **internally generated power.** Waste heat boilers from the steel works contribute to steam production.

A mixed iron works is **linked** to the following **other sectors**:

- The raw materials (ores, coal, limestone) must be mined in large quantities in open cast or deep mines. (See environmental briefs Surface Mining and Underground Mining).
- Ores must be dressed (see environmental brief Minerals - Handling and Processing).
- Efficient transport routes (canals, railways or roads) are required for **transporting raw materials** and products. For environmental protection reasons, transport should mainly be via inland waterways and railways. Whether the location of the iron works is chosen because of where the ore, coal or sales market is situated, high-capacity transport facilities must always be provided.
- **Coke** of specified quality must be supplied for the blast furnace by a coking plant. Reference should be made to the environmental brief Coking Plants, Coal to-gas Plants, Gas Production and Distribution to assess the environmental impacts associated with coke production.
- In view of the quantities of cooling water needed, an adequate **water supply** must be available. To avoid the adverse consequences of drawing excessive quantities of water from groundwater or surface water resources, extensive recirculation systems must be provided, internal treatment of wastewater and cooling water. Water consumption must be in harmony with the **general water framwork planning**.
- The large workforce of a mixed iron works may result in the disorganised

development of housing at an insufficient distance from the plant. This can lead to **water shortages,** unsatisfactory wastewater treatment and disorganised dumps, plus immission burdens affecting the **areas of habitation.**

- Other sectors directly or indirectly linked to the iron and steel industry are: **lime kiln plants, cement works, ferroalloy production plants, power generating plants** and **slag and dust recycling plants.** The above plants and establishments are associated with considerable potential atmospheric burdens. Reference is made to the relevant briefs.
- A **general or single-purpose dump** is to be provided for non-recyclable **residual and waste materials** including furnace debris from the metallurgical processes with hazardous pollutants. These should be classified according to criteria of environmentally acceptable final storage (see environmental brief Disposal of Hazardous Waste).

5. Summary assessment of environment relevance

The **establishment** of iron and steel production plants in areas not previously used for industry will have an impact on the landscape. **Environmental damage can be reduced** by **selecting locations** with relatively insensitive landscapes where there is unlikely to be any great effect on the regional productiveness of the natural environment.

The **environmental burdens** imposed by an iron and steel making plant and related technologies relate to the air, water, soil, flora and fauna, waste, noise and vibration.

Efficient separators are available for reducing **dust emissions.** Important in this regard is the **continuous monitoring** of the operation of these separators using suitable measuring equipment. Since a large proportion of the separated dust can be re-utilised in the process, **high-performance gas cleaning systems** are desirable, not only for environmental protection reasons but also in the interests of **economy.** Increasing attention is being paid to **random dust sources**, e.g. from working bays. Tried and tested **collection systems** are available for this purpose. High dust immissions occur in the vicinity of iron works. Although high grade cleaning of waste gases reduces dust emissions, **dust emissions** for the iron works as a whole are between 1 and 3 kg/t, depending on the number of installed process stages and the extent of dust reduction from diffuse sources. 1 kg/t should be regarded as an optimum value. Studies should be carried out in all cases to determine whether **agriculture in the vicinity of the works** is being impaired by contamination over wide areas with phytotoxic and zootoxic heavy metals, especially zinc, copper, chromium, nickel and lead, taking into account long-term deposition and accumulation in the soil. Heavy metals, especially cadmium and mercury, can be injurious to human health through accumulation in the soil and in plants, with increased absorption through the food chain. **Conflicts** can be **avoided** or **diminished** by **consulting** the affected population groups at an early stage, possibly developing and planning new sources of employment (see also Vol. III, Compendium of Environmental Standards).

As the **increased environmental burden** poses **additional health risks** and hazards, e.g. for women and children (during pregnancy etc.), **adequate medical care** should be provided in the project region.

In some respects **air protection measures** lead to a **shifting of problems**, e.g. where separated residues cannot be recycled. A high degree of **recycling of the material and energy** present in dusts, sludges and gases is a basic requirement for environmental compatibility, and one that can be met. For materials which cannot be recycled, a **dumping system** must be selected which will enable environmentally acceptable final dumping.

Although technological development in iron works has led to high water consumption, use of water in the plants can be minimised by recycling as much as 80% and through the use of **closed cooling circuits.** The standards applicable to the cleaning of wastewater contaminated with heavy metals must be raised from the level of the general rules previously applicable in Germany to a truly "state-of-the-art" level.

Noise levels can be minimised by extensive **noise reduction measures**. However it is also important to ensure an **adequate distance** between the works site and neighbouring areas of habitation.

Possible ways of preventing adverse environmental impacts through state-of-the-art emission reductions in **old plants** include (in the process engineering area) replacing old converter techniques for steel production with low-emission converters and electric furnaces and introducing continuous casting in approximately final dimension form. In the waste gas and air purification area, the use of multistage separators, fine dust separators and the interception of diffuse emission sources is also possible in old plants. Increased recycling of residues and water will help reduce the environmental burdens imposed by old plants. Secondary noise reduction measures are more difficult to implement than primary measures.

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50. Non-ferrous metals

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1. Scope

Since the **non-ferrous metals** sector covers a multitude of individual **products, charge materials, fuels** and **processes**, this brief can only deal with a few **examples** of the **principal industrial non-ferrous metals.** Environmental impacts and protection measures in the production and processing of **aluminium, copper, lead** and **zinc** are dealt with as representative of the large number of other non-ferrous metals as well.

The non-ferrous metals sector comprises **the subdivisions:**

- smelting of appropriately pretreated primary raw metals to produce metals
- processing recycling material in secondary smelting plants, and
- processing of metals to produce standard commercial billets and blanks.

2. Environmental impacts and protective measures

The following deals primarily with the environmental factors arising in the **application of current standard processes**. For projects using **pyrometallurgical processes** these are primarily **air protection measures**; **slags** are also produced which, depending on their composition, can be a danger to soil, water and living things. In **hydrometallurgical treatment processes,** measures to **protect water and soil** predominate.

Since most processes generate **noise,** the possibility of noise pollution occurring both in the work-place and in the neighbourhood must be taken into account.

Non-ferrous metal production plants occupy a considerable amount of **space** to accommodate the works site with adjoining areas and connecting roads.

Different quantities of energy are required depending on the production process. The **choice of location** partly depends on the availability of sufficient low-cost electricity, e.g. in the case of aluminium production. An encapsulated furnace producing aluminium by igneous electrolysis, with a current load of 200 kA and d.c. voltage of 4.2 V requires approximately 13 kWh/kg aluminium. Zinc production with the stages of roasting, leaching, neutralization, leachate cleaning and electrolysis requires 4 kWh/kg zinc. Values for copper production are somewhat higher. Energy requirements of **secondary smelting plants** are considerably lower: 20% of the primary smelting energy requirement with 100% scrap copper, around 40% with 100% scrap zinc and 10% with 100% scrap aluminium.

2.1 Aluminium extraction

The **Bayer process** is used almost exclusively for producing aluminium oxide, the charge material for primary aluminium smelting plants. Bauxite is treated with soda lye under pressure and heat in autoclaves to produce aluminium hydroxide and **red mud**. The latter is separated, washed and filtered, and may be recyclable or may have to be dumped. After sedimentation and filtration, the aluminium hydroxide is converted to aluminium oxide (alumina) by fluidized bed calcination at around 1100C.

Large quantities of **red mud** (1 - 2 t/d Al_2O_3) are produced. Depending on its composition and the situation in the country in question, it should be used for **extracting** aluminium oxide and iron, producing flocculation agents for wastewater cleaning or the manufacture of building materials. Red mud which cannot be further processed must be **dumped.** Where it is stored on a dump, **special requirements** must be met in respect of sealing and treatment of percolation water. Dumping should be on a single-purpose dump subject to continuous supervision.

A considerable amount of fine dust may be produced upon **loading, unloading and transport of fine-grained materials** (bauxite, alumina) unless **enclosed conveyor systems** and **suitable storage facilities** are provided. Waste gas from the calcination furnaces contains dust with an aluminium oxide content which is deposited in dry filters and recirculated. Dust emissions in cleaned waste gas are under 50 mg/m^3.

The process most commonly used for **extracting pure aluminium** is **igneous electrolysis**. Aluminium oxide at approximately 950C is dissolved in a molten mixture of aluminium fluoride and cryolite and separated by direct current into pure aluminium and oxygen. The liquid aluminium is periodically drawn off and cast.

The following **emissions and raw materials** occur with the **extraction of pure aluminium:**

- primary alumina dust during storage, transport and charging;
- primary dust during anode production (petroleum coke etc.);
- volatile binding agents, fluorine from anode residues in the waste gas from the anode burning kilns;
- fluorides (dust and gaseous form) in the pot waste gas containing CO/CO_2;
hydrogen fluoride gas is highly corrosive, harmful to health and the environment (also affects plant growth);
- used cathodes, containing fluoride;
- furnace breakage materials with fluoride components;
- wastewater.

The following individual protection measures are necessary:

Fine dust: Use of enclosed conveying systems (e.g. pneumatic conveyors).

Anode production: Extraction of dust and gaseous emissions, electrostatic waste gas cleaning, wet-chemical fluorine separation. Use of fabric filters permits clean gas dust concentrations of under 20 mg/m^3 and fluorine contents of under 1 mg/m^3.

Pots: Pot encapsulation with anode gas extraction and waste gas cleaning, wet chemical fluorine recycling or combined dedusting and dry absorption in the Al_2O_3 fluidized bed with direct recirculation. Wet chemical separation with water recirculation produces a sludge which, after drying, can only be partly returned to the process. Dry absorption and return of the filter dust to the process is preferable as this relieves the burden on the water circuit. Clean gas dust contents of under 30 mg/m^3 and fluorine compounds of under 1 mg/m^3 are obtained with encased, centrally controlled, large-capacity furnaces with computerised waste gas regulation and dry absorption with fabric filter.

Cell house: Shop air extraction and cleaning is compulsory with non-encased furnaces. Can be retrofitted.

Cathode and furnace Dumping only on specially protected, single-purpose breakage: dumps Cryolite, used as a fluxing agent for the electrolysis, can be obtained by processing (fluorine recycling).

Wastewater: The discharge of wastewater from aluminium oxide production and aluminium smelting must satisfy the requirements laid down under the generally recognised standards regarding chemical oxygen demand for aluminium and fluorides.

With respect to **noise**, a distinction is made between noise emissions affecting the **neighbourhood** and those affecting the **workplace.** Emission from main noise sources can be restricted by encapsulation and by means of silencers on air intakes and outlets. A **noise reduction plan** should be prepared during the planning phase.

2.2 Heavy metal ore smelting

The **composition** of the concentrates or raw materials is crucial for the applicable **smelting process** and thus also for the nature and quantity of the **environmental pollutants** arising. Sulphidic ore concentrates are thus mostly smelted by **pyrometallurgical processes,** whilst **hydrometallurgical processes are employed for** oxidic, sulphidic-oxidic and complex ores.

Combined processes are also used in which, for instance, material roasted by a pyrometallurgical process undergoes further treatment by hydrometallurgy. The charge material is ore enriched by beneficiation.

Pyrometallurgical process stages

Roasting: Partial or total desulphurization (dead roasting) of the charge material;

Sinter roasting: Roasting of sulphur with admission of air (conversion of sulphides to metal oxides and SO_2 gas) with simultaneous agglomeration of the roasted material for use in shaft furnaces;

Rolling: Metal oxide enrichment by controlled volatilization (Zn);

Smelting: Separation of gangue (slags): production of high grade metal sulphides (Cu_2S) by partial combustion of the sulphur content and reduction of metal oxides (PbO, ZnO) under coke combustion with air admission;

Fuming: Conversion of metal sulphide to metal in a converter;

Pyrometallurgical Cleaning molten metal of oxygen, sulphur, impurities refining: and tramp metals by intermetallic precipitation, slagging and/or volatilization;

Slag cleaning: Thermal processing of slags to extract metal components.

Numerous **emissions and residual materials** occur with the above processes:

- Waste gases of various origins
- Primary dust from the charge material,
- Dusts from volatilized metals, including lead, zinc, arsenic, tin, cadmium, mercury, selenium, tellurium and their compounds (condensed after cooling),
- gaseous materials including SO_2, HCl, HF, CO, CO_2;
- Wastewater from coolant circuits and waste gas scrubbing;
- Final slags with residual metal contents, sulphates, sulphides; possibility of polychlorinated dibenzo-dioxins and -furans with chlorinating methods (e.g. copper roast leaching process);

- Furnace breakage materials, containing arsenic, lead, cadmium, mercury and cyanide.

For protective measures to be effective, it is **essential** that all emissions, including diffuse emissions of gas and dust, be **efficiently intercepted** at their points of origin. Diffuse emissions can be intercepted by **hoods, covers** or **encapsulation**, also by **constructional measures** such as encasement of conveyor belts or enclosed bays. Roasting furnaces should not be outdoor installations.

Dust: Waste gases are normally dedusted in dry filter systems (cyclones, electrostatic precipitators, fabric filters). Dedusting efficiency of up to 99.9% is possible, but depends on the permissible solid or pollutant content. Dusts can also be separated with fabric filters in lead smelting plants. Good separation efficiency is particularly important for the environment because waste gas from smelting contains toxic substances such as arsenic, antimony and lead in the form of fine dust. High-performance filtering separators have proved effective for fine dust separation.

Dust recycling for enriching and recovering metals. Separate pyrometallurgical or hydrometallurgical processing of tramp metals, for example As, Cd. Fabric filters are the principal method of dust separation. Clean gas dust contents of 10 mg/m^3 can be obtained. Best values are around 1 mg/m^3, e.g. in lead smelting plants.

SO_2 gas: Removed by waste gas scrubbing followed by neutralization. SO_2 concentrations in waste gas of over 3.5% are suitable for sulphuric acid production. In certain circumstances liquid SO_2, gypsum or elementary sulphur can be produced as a possible preliminary stage for industrial usage. Wet chemical waste gas cleaning processes are used for lower SO_2 concentrations. Only limited SO_2 concentrations and overall quantities may be discharged via chimneys.

Oil mists: If oil mists are present in the waste gases from shaft furnaces on account of the charge material, waste gases must undergo thermal afterburning.

Final slags/ Slags and furnace breakage material should be stored furnace breakage: in a specially protected single-purpose dump, since toxic and water-polluting substances such as heavy
metals may be released through leaching and weathering. Depending on residual metal content and
concentrations of other substances such as sulphides, sulphates, dioxins and furans, may possibly be used for road construction or reprocessing, or may have to be discarded.

Wastewater: Wastewater from waste gas scrubbing and slag granulation is polluted with heavy metals. Dissolved and undissolved metallic compounds in communal treatment plants lead to excessive metal concentrations in sewage sludges, restricting or preventing agricultural use.

Measures for reducing pollutant loads include minimizing wastewater volumetric flow by recirculation, recycling of treated wastewater and separating wastewater requiring treatment from that not requiring treatment. Extremely high standards must be applied to the discharge of wastewater with metal compounds toxic to humans and the ecosystem. State-of-the-art wastewater treatment systems include selective ion exchangers, microfiltration systems, reversal osmosis and thermal concentration processes. Production-specific concentrations of cadmium, mercury, lead, zinc, arsenic, copper, nickel and chromium should be limited.

Significant waste gas and emission reductions are achieved by combining several process steps in **modern processes** such as the flash cyclone reactor and the flash smelting method. Trials in a copper smelting plant and a lead smelting plant yielded reductions of 75%.

Hydrometallurgical processes

Charge materials are oxidic ores, pretreated sulphidic ore concentrates which can be hydrometallurgically treated, or sulphidic concentrates which undergo oxidizing leaching. Hydrometallurgy processes also include extraction and refinement electrolysis.

Leaching: Treatment and lixiviation of the metals to be recovered, e.g. with dilute sulphuric acid for zinc production. For dump leaching in the case of very low-grade ores (bottom sealing necessary for soil and ground water protection);

Enrichment: Concentration of weak solutions by fluid extraction, using an organic solvent with simultaneous leachate cleaning.

Cleaning: Separation of accompanying substances and impurities by solids-fluid extraction and/or precipitation (hydroxide or sulphide precipitation, cementation);

Extraction: Electrolytic metal deposition with insoluble anodes (e.g. with Zn, Cu);

Refining: Electrolytic metal deposition with soluble anodes (e.g. with Cu, Pb).

The following environmentally relevant **emissions and substances** may be produced with the above processes:

Wastewater: Greater or lesser quantities of zootoxic and phytotoxic heavy metal components may be present in the wastewater, depending on the charge materials.

Leachate residues: Leachate residues contain metallic compounds harmful to the environment.

Waste gases: Sulphuric acid mists are produced in the extraction electrolysis; metal-containing vapours, e.g. in crude copper anode furnaces; organic solvents, e.g. xerosin, during liquid extraction in the enrichment process.

Anode sludge: This sludge contains metals and metal compounds, e.g. gold, silver, lead, tin, arsenic, antimony.

Spent electrolyte: The electrolyte contains dissolved metallic compounds of iron, nickel, zinc, arsenic and cobalt.

The following **individual protection measures** are necessary:

Wastewater: The wastewater volume must be reduced by appropriate measures, e.g. recirculation, recycling. Wastewater containing heavy metal pollutants must be treated by state-of-the-art methods. Wastewater contaminated with e.g. cadmium and mercury must be channelled and treated separately.

For wastewater treatment, especially low production-specific concentrations are to be stipulated, with residual concentrations of under 1 mg/l Cd and under 0.1 mg/l Hg to be achieved. Suitable processes include ion exchange, ultrafiltration and electrolysis.

Leachate residues: Residues must be converted by washing and neutralization processes to form compounds suitable for final dumping. Where technically possible, solvent residues are to be eliminated.

Waste gases: Permissible work-place concentrations for sulphuric acid mist can be achieved by appropriate room air ducting and, where necessary, waste air scrubbing.

By equipping a crude copper anode furnace with fabric filters, it was possible to separate gaseous metallic compounds to clean gas concentrations of 0.001 mg cadmium/m^3, 0.05 mg lead/m^3 and 1.9 mg/arsenic/m^3. With liquid extraction using organic solvents, precautions must be taken against combustion and explosion and for fire fighting.

Anode sludge/ Special hydrometallurgical or pyrometallurgical electrolyte: measures are to be employed for the phased recovery of useful materials and the extraction of tramp metals; e.g. electrolytic deposition of arsenic and antimony or precipitation of nickel, iron or cobalt.

The **extraction of zinc** from zinc blende or galmei inevitably yields 3 to 4 kg **cadmium** per tonne of zinc as an alloy element in crude zinc or in the form of residues. Cadmium is extracted in primary zinc smelting plants by dry and wet absorption processes. The generally preferred **wet processes** and **electrolytic cadmium extraction** result in **no direct production of cadmium dusts**. The **waste gases** resulting from the smelting of cadmium to produce commercial formats can be introduced to the air for roasting, in order to achieve total waste gas cleaning.

Due to the **toxic effects** of cadmium, **strict requirements** must be imposed on **work-place hygiene** and **waste air and water cleaning**. In heavy metal ore smelting operations, **main noise sources** are wherever possible to be restricted by encapsulation and by means of silencers on air intakes and outlets. A **noise reduction plan** should be prepared at the project planning stage. In the case of operations generating high levels of noise, one should preferably begin by damping or eliminating occurrences and noise sources which arise only periodically.

To protect **work-places** from noise, installations should be extensively **automated** and equipped with appropriate control rooms. **Protective equipment** includes fireproof clothing, breathing equipment and ear protectors, depending on where they are working; protective helmets and safety footwear must be worn in all areas.

Measures for safety in the work-place and to protect the soil of the works site include all precautions to prevent the discharge of water-polluting substances. **Special attention** is to be paid to installations for producing, handling and using water-polluting substances. Relevant precautions include storage tanks with leakproof drip trays, overfilling safeguards, sealed and impermeable floor surfaces and leak testing, and these should be set forth in a **manual**.

2.3 Secondary smelting plants

Secondary smelting plants process mainly **recycling material** (shredder scrap, cables, batteries etc.), heavily contaminated mixed scrap, production scrap with alloy constituents that are difficult to remove, also slags, dross and other metalliferous residues. Predominantly **pyrometallurgical processes** are employed for metal recovery.

Environmental burdens stem mainly from **impurities and pollutants present in the charge material**, e.g. oil, paint, plastics, solvents or salts.

Special characteristics of the **emissions and substances** and requisite safeguards are as follows:

Aluminium scrap melting plants

Salt slags: Aluminium scrap is usually melted down in rotary or hearth type furnaces under a layer of liquid salt to prevent ingress of air. The salt absorbs impurities present in the scrap and occurring during the melt-down process and produces salt slag (0.5 t/t Al).

Dumping these salt slags seriously pollutes the dump percolation water, therefore salt slag should be processed and returned to the melting process.

Waste gases: The molten aluminium is refined in converters using chlorine gas. The waste gases contain dusts, gaseous chlorine and fluorine compounds and chlorine gas; they may also contain organic substances which, depending on the operating conditions, may include traces of especially environmentally hazardous materials such as polychlorinated dibenzo-dioxins and -furans. Adequate separation of the dusts and inorganic compounds is achieved by dry absorption and fabric filters. Emissions of organic substances can be minimized by scrap sorting and cleaning or by special thermal afterburning of the waste gases.

Copper scrap melting plants

Dust: When melting down copper-bearing residues, the interception and dry separation of emissions produced on charging and running-off are particularly important. Where oil mist occurs due to the impurity of the copper scrap, waste gases must undergo thermal afterburning before dust separation. For ecological and economic reasons, melting down should take place in a converter with top lances in a shop with waste air collection and cleaning rather than in shaft furnaces.

Lead scrap melting plants

Waste gases: When recycling scrap batteries, PVC residues may give rise to gaseous inorganic chlorine compounds which are absorbed in the dust and in the slag.

Depending on the operating conditions, small quantities of polychlorinated dibenzo-dioxins and -furans may be present in the waste gases when recycling scrap cables. Emissions of health-endangering dioxins and furans can be restricted by careful sorting of scrap lead, scrap batteries and cables. Trials are in progress on activated-charcoal-based equipment for separation of these substances. Cleaning of scrap batteries results in varying quantities of battery acid (sulphuric acid) entering the washing water. The washing water is contaminated with lead, antimony, cadmium, arsenic and zinc. Separate interception and treatment is necessary.

2.4 Non-ferrous metal semifinishing works

In semifinishing works, the **main problems of maintaining clean air** stem from the upstream format foundries. These use large amounts of **defined scrap** in addition to **primary metal** which may call for pyrometallurgical smelting refining (e.g. with chlorine gas compounds in the case of Al).

Oily and plastic-coated scrap produces soot, oil mist, chlorine- and fluorine-bearing acid mist and similar substances on being melted down. Formation of polyhalogenated dibenzo-dioxins and -furans cannot be ruled out. For this reason scrap should be precleaned in fuming furnaces with afterburning chambers; depending on the permissible level of purity, waste gases are to be cleaned in electrostatic precipitators and/or gas scrubbers.

Waste gas from melting furnaces can contain metal oxides, volatile metalliferous vapours and halogen compounds which must be separated in dust filters or waste gas scrubbers. Through **process automation** and the use of **additional reactors**, even low-capacity secondary smelting plants (2,400 t/a) can achieve **low clean gas emission values**, e.g. 5 mg/m^3 dust, less than 1 mg/m^3 fluorine compounds, by chemisorption combined with cyclone and fabric filter. Separation efficiency for chlorine compounds can be as high as 98%.

Cooling bays for gas-emitting dross and slag are also to be connected to **centralized waste air extraction systems.**

Alkaline or acid solutions should be used for **degreasing, cleaning and pickling metal surfaces**. Organic solvents containing halogens should be avoided. **Flushing water** and used pickling and washing liquids are to be **treated** in neutralization plants.

Sludge residues are either pyrometallurgically **processed** in a smelting plant or, if they contain no pollutants, **dumped. Vapours** from heated pickling and rinsing baths must be extracted, precipitated by gas scrubbers and **neutralized.** Polluted waste must be placed on protected **dumps** with collection of percolation water.

As non-ferrous metal semifinishing plants are frequently situated **close to residential zones**, consideration must be given to **noise reduction measures** and the necessary **distance.**

3. Notes on the analysis and evaluation of environmental impacts

Non-ferrous metal industrial operations using thermochemical or pyrometallurgical processes produce **considerable quantities of waste gases** laden with environmentally harmful substances. **Air protection measures** must therefore be a priority.

The following **examples** illustrate the possible **pollutant content** of the waste gases:

- aluminium smelting plant, toxic fluorine components in the anode gas raw gas approx. 10 kg F/t Al
- copper smelting plant, sulphur dioxide in the waste gas raw gas approx. 2.6 t

SO_2/t Cu

The values indicate that even in regions with low levels of existing pollution, waste gases from metal smelting plants must **on no account** be discharged **uncleaned. Wet** and **dry processes** are available for cleaning, dry processes being preferred for ecological and economic reasons.

Continuous monitoring involving measurements to verify the effectiveness of the separation systems is necessary both after erection of the plant and during its operation. Detailed descriptions for carrying out **emission and immission measurements** are contained in the guidelines of the German Association of Engineers *VDI*. In Germany the obligatory **emission and immission values** are detailed in TA-Luft (Technical Instructions on Air Quality Control).

In plants using **hydrometallurgical processes**, to reduce environmentally harmful substances to a minimum, **intermediate products and residues** must undergo repeated chemical treatment, filtration, electrolytic precipitation or scrubbing with subsequent neutralization. **Wastewater** from gas scrubbing or pickling plants may only be returned to receiving bodies of water once it has been chemically neutralized and freed of solids. **Guideline values** for permitted pollutant concentrations must be established for discharging wastewater in accordance with the state of art. **Reference values** may be obtained from the regulations in force in Germany. In every case care must be taken to ensure that **drinking water** and other water resources are not impaired. **Analytical processes** have been defined under German DIN standards to determine pollutant concentrations in wastewater; in Germany these are detailed in *Allgemeine Verwaltungsvorschriften [*General Administrative Regulations]. **Routine measurements** are also to be carried out to monitor the efficiency of water treatment and clarification plants. The scope of measurements and the inspection and maintenance intervals of wastewater - and waste gas - cleaning systems must be defined in an **operating manual**.

Contaminated material is to be **stored** in such a way as to prevent soil and groundwater contamination. Where possible, **single-purpose dumps** should be established, with sealing and percolation water collection and treatment systems which satisfy stringent requirements.

As in Germany, **works environmental protection officers** should be deployed in non-ferrous metal works who are totally independent of the production side. They are obliged to monitor adherence to the regulations.

In addition to monitoring external pollutant discharge, internal **work-places** must also be inspected for pollutant concentrations, noise and safety. Suitably qualified **safety officers** and a **works doctor** should be appointed for these purposes.

4. Interaction with other sectors

Normal **annual production capacities** of newer non-ferrous metal smelting plants are between 50,000 and 100,000 t. Allowance must be made for future **capacity expansions**. Due to the quantity of **land occupied** and the **environmental pollution** involved, projects cannot be considered in isolation. As early as the initial location selection phase, existing **prior pollution** of air, water and soil must be taken into account, making adequate allowance for the **additional burdens** imposed by such an industrial complex. As early as the planning phase, and when defining permissible immissions, effects on the environment must be considered from the point of view of community development. Adequate distancing from the nearest residential zones is to be guaranteed. Further details are contained in the **environmental brief Planning of Locations for Trade and Industry.**

Raw materials for smelting plants have to be extracted in large quantities from underground or surface mines. The environmental briefs on **mining** provide information on the environmental impacts. Efficient transport routes are necessary for transporting charge materials and products. Details are contained in the briefs **Road Traffic, Railways and Railway Operation** and **Shipping**.

A special **secondary effect** of the use of electrolytic processes is that their profitability, and particularly that of an aluminium smelting plant depends on the availability of cheap electricity. Additional pollution results from the erection or extension of power stations and the associated construction, particularly of hydraulic engineering works (see environmental briefs **Thermal Power Stations** and **Power Transmission and Distribution)**.

A single-purpose dump must be established for non-recyclable products and waste, including slag and furnace breakage material (see environmental brief on **Disposal of Hazardous Waste** and **Volume III, Compendium of Environmental Standards).**

5. Summary assessment of environmental relevance

Processes and raw materials utilized in non-ferrous metal smelting plants for extracting aluminium, copper, lead and zinc, and also refining and smelting plants for further processing, produce **emissions and raw materials** which can pollute the environment. Of special significance are **heavy metals** which endanger health and in some cases are carcinogenic. In many countries this concerns especially the poorer sections of the population who are particularly at risk due to malnutrition and illness. The same of course applies to metal smelting plants other than those mentioned here.

Environmental damage can be reduced by **selecting locations** with relatively insensitive landscapes where there is unlikely to be any great effect on the regional productiveness of the natural environment. It is also necessary to **exclude regions** that are already heavily burdened with high existing or background levels of fluorine compounds and heavy metals. In this regard it should be noted that anthropogenic heavy metals are often more readily plant-available than lithogenic or pedogenic heavy metals.

Pyrometallurgical processes cause mainly **air pollution** in the form of gases, mists and dusts which must be minimized in gas scrubbers or returned for further processing. Apart from the ecological benefit, this form of **emission reduction** has the **economic benefit** of **recovering** valuable metals or producing sulphuric acids. Similar conditions exist for **secondary smelting plants** but with the additional problem of polluted charge materials. Depending on the operating conditions, halogen-bearing pollutants combined with organic materials are a particular potential source of polyhalogenated dioxin and furan emissions (waste gas emission concentrations of the order of nanograms).

Emissions and residues from **hydrometallurgical processes** on the other hand can pollute **wastewater** and **dumps. Recycling of water** in the circulation system is very important. Though it is state-of-the-art practice to recirculate **liquid process materials** such as acids, alkalies or solvents by regeneration, thereby **reducing residues**, these must be subsequently **processed** and the waste products **neutralized** in more or less costly stages to recover valuable metals and/or extract pollutants. Checks must be made in every case to determine whether **pollution of groundwater or surface water** is possible due to the storage or emission of primary, intermediate or end products. Pollutant yield and hence the necessary outlay for pollutant reduction is significantly lower in the case of semifinishing works.

A survey should be conducted in every case to determine whether **agricultural use of the land in the vicinity of the works** will be impaired by large-area pollution with phytotoxic and zootoxic heavy metals, especially zinc, copper, chromium, nickel and lead, taking into account long-term deposition, accumulation and reactivity in the soil. The environmental risk resulting from heavy metals in the soil must be distinguished according to the form of bonding of their elements which in turn depends on their origin.

Heavy metals, especially **cadmium**, can be injurious to human health through accumulation in the soil and in plants, with increased absorption through the food chain, leading in particular to kidney damage. **Preliminary calculations** of the expected additional environmental burdens are necessary for assessing these **indirect effects** via the air - soil - food chain. As a precaution, it is advisable to restrict agriculture in the immediate vicinity. **Conflicts** can be **avoided** or **diminished** by **consulting** the affected population groups at an early stage, possibly developing and planning new sources of employment. The question as to whether the **increased environmental pollution** poses **additional health risks** and hazards, e.g. for women and children (during pregnancy etc.) should be investigated, and **adequate medical care** provided. In addition to the pollution burdens, attention must also be paid to the **noise** emitted by the plant machinery. Depending on the plant design, noise levels as high as 125 dB(A) may be emitted. Noise levels can be minimized by **noise reduction measures** which are to be specified in a noise reduction plan. The wearing of **personal ear protection** must be obligatory in **workplaces** with noise levels in excess of 85 dB(A) and must be monitored.

For environmental protection measures to be effective, it is vital that personnel should be made **sensitive to the issues** and **receive appropriate training**. Although the smelting industry already has a range of **proven methods and processes** at its disposal for effective pollution control, their application can be **excessively cost-intensive** where pollutant emissions are too low for improvements to be economic but too high to be ecologically harmless. In these cases, bearing in mind the long-term effects of heavy metal pollution, one must give **considerable weight to the needs of environmental protection,** even putting this before the profitability of the individual plant.

The emphasis of current **development work** is towards totally enclosed **circuits** in the production system. The aim is to enclose the circuit to prevent harmful effects on the biosphere through ever better utilization of charge material, production of pure intermediate and end products without recourse to dumping, with improved emission protection and recycling of separated dusts and solids.

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51. Mechanical engineering, workshops, shipyards

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1. Scope

The different branches of mechanical engineering are concerned with the **machining and processing of ferrous and non-ferrous metals.** This covers the whole range of **production processes**, which can be **subdivided** as follows:

A:	Metal cutting		
	* drilling	* milling	* turning
	* planing	* broaching	* sawing

	* filing	* honing	* grinding
	* lapping	* sandblasting	* chiselling
B:	Non-cutting processes		
	Thermal bonding		
	* oxy-acetylene welding	* electric welding	
	* inert-gas-shielded welding	* submerged arc welding	
	* build-up welding		
	Thermal cutting		
	* oxy-acetylene cutting	* plasma cutting	
	Forming		
	* forging	* deep drawing	* bending
	Dividing		
	* punching	* cutting	* shearing
	* nibbling		
	Jointing		
	* riveting	* adhesive bonding	* soldering

	Surface treatment		
	* surface cleaning	* degreasing	* pickling
	* surface coating	* phosphating	* chromatizing
	* electroplating	* enamelling	*hot-dip galvanizing
	* anodizing	* painting, lacquering	* surface annealing

The raw materials used in these processes may have high environmental pollution potential (e.g. heavy metals), and hazardous production materials may be used (e.g. cleaning agents containing chlorinated hydrocarbons). At the same time, vapours, heat and noise are generated, together with various waste products and wastewater, leading to adverse effects on the environment and on man, especially in enclosed areas.

In shipyards, the main process is welding. This is made additionally hazardous by the fact that welders working on bulkheads often have to work in enclosed areas, which further aggravates the health risks discussed below.

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2. Environmental impacts and protective measures

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A product undergoes numerous production stages in the course of the metalworking process. The environmental impacts of these stages affect the workplace and hence the people working there. They also affect the air, water and soil.

Due to their proximity to the point of origin, it is the workforce who are most seriously exposed to the production hazards. In highly industrialised countries this is the subject of comprehensive worker protection rules. The workplace hazards are listed below, taking as examples the most important and environmentally relevant machining processes. This is followed by a description of the wider environmental effects including the problems of waste disposal.

2.1 Potential hazards of selected operations

2.1.1 Metal cutting

Machining processes such as drilling, milling, turning, cutting, honing, grinding etc. make use of oils and oil preparations for lubricating and cooling tools and workpieces, to prevent overheating and possible melting of the workpiece and tool. Oils are dosed by spraying or pouring systems at rates of up to 100 litre/min. in order to dissipate heat. The spraying of

moving and sometimes very hot tools and workpieces produces vapours containing droplets known as aerosols.

Metalworking techniques require appropriate coolants which must combine several different properties (non-foaming, corrosion-inhibiting, non-decomposing etc.).

Such a wide range of properties can only be achieved through the addition of varying quantities of chemical additives. These are added to the coolants in the form of non-water-miscible cutting oils or water-miscible concentrates.

More than 300 individual substances are used as coolant components. The following table divides these into substance groups by areas of application.

Substance group	**Reason for use**	**Examples**
Mineral oil	Lubrication effect	Hydrocarbons with different boiling ranges; fatty oil; esters
Polar additives	Enhanced lubrication properties	Natural fats and oils of synthetic esters
EP additives	To prevent micro-welds between metal surfaces at high pressures and	Sulphurized fats and oils, compounds containing phosphorous,

	temperatures	compounds containing chlorine
Anti-corrosion additives	To prevent rusting of metal surfaces	Alkano-amines, sulphonates, organic boron compounds, sodium nitrite
Anti-misting additives	To prevent breakdown of the oil and thus generate less mist	High molecular substances
Anti-ageing additives	To prevent reactions within the coolant	Organic sulphides, zinc dithiophosphates, aromatic amines
Solid lubricants	To improve lubrication	Graphites, molybdenum sulphides, ammonium molybdenum
Emulsifiers	To combine oils with water	Surfactants, petroleum sulphonates, alkali soaps, amine soaps
Foam-inhibitors	To prevent foaming	Silicon polymers, tributyl phosphate

Biocides	To prevent formation of bacteria/fungus	Formaldehyde, phenol, formaldehyde derivatives, cathon MW

A significant increase in certain occupational diseases has occurred parallel with the introduction of the coolants which are now commonplace. According to scientific findings, diseases of the skin and respiratory tracts and cancer may occur.

Where coolant use is unavoidable, mist extraction as close as possible to the point of origin or encapsulation is necessary. Consistent use must be made of personal protection measures such as the wearing of protective clothing and the use of special skin protection substances. Factories should produce skin protection plans.

Bacteria which can have severe effects on health can occur due to the organic nature of coolants. Bacteria formation is promoted by warm/hot ambient temperatures. Anti-bacterial additives are introduced to counter this. Timely replacement of coolants avoids the need for high doses of anti-bacterial additives, which also represent a health hazard. However, this increases the total quantity of waste to be disposed of. Proper storage of "spent" coolants and subsequent separation of emulsified oils and greases, and also of metal compounds and other components, is imperative.

Safety data sheets informing of the danger of coolants and instructions for use should be displayed in the national language(s). It is important that staff are aware of the long-term

dangers of coolants; a particular difficulty here being the often creamy, pleasant smelling and seemingly harmless nature of coolants.

No generally applicable limit values exist for coolants in the breathing air. The only guide is the relevant MAK values9) for the individual substances. The management should find out which are the most environment-friendly coolants and ensure that these are procured.

9) The term MAK (maximum allowable concentration) in Germany refers to the maximum possible concentration of a substance in the air of the workplace, in the form of gas, vapour or suspended matter.

2.1.2 Cleaning and degreasing of workpieces

For subsequent surface treatment, adhesive or thermal bonding etc., workpieces have to be freed of substances such as oils, fats, resin, wax, cellulose, rubber or plastics. Solvents are widely used for this purpose. Workpieces can be degreased and cleaned by various methods, for instance by cold, hot and/or vapour degreasing or combined processes.

Cold cleaning frequently involves the use at room temperature in open baths of solvent mixtures whose precise composition is not known to the user. Mixed with air, the vapours of these solvents or solvent mixtures can be explosive. Most solvents represent a health hazard for man.

Solvents are classified as organic compounds such as hydrocarbons, halogenated hydrocarbons, ethers (diethyl-ether, tetrohydrofuran, dioxan), ketones (acetones, methylethylketone) and organic alkalis (sodium hydroxide solution, ammonia) and acids (hydrochloric acid, nitric acid, sulphuric acid).

The most important halogenated hydrocarbons are chlorinated hydrocarbons (CHCs), such as tri-, tetra-, perchloroethylene, dichloromethane, tetrachloroethane etc.10) On account of their grease-dissolving properties and high volatility, CHCs are used in almost every branch of metal working as cleaning agents in cold cleaners and in hot degreasing. The high volatility ensures quick drying after cleaning, but also means it is necessary to monitor solvent concentrations in the workplace. Through skin contact and inhalation, CHCs can damage mucous membranes, central nervous system, liver, kidneys and lungs.

10) The best known are CFCs (chlorofluorocarbons) used in other application e.g. as refrigerants. CFCs are partially responsible for the destruction of the vital ozone layer in the atmosphere. CFCs and carbon tetrachlorides and certain other chlorinated hydrocarbons are banned in Germany under the CFC halogen prohibition directive of 6 May 1991 and the chloro-aliphatic compounds directive.

In addition, most solvents are inflammable and represent a particular pollution hazard for water.

Alternative processes use alkaline aqueous solutions (with surfactants and other washing components in varying concentrations) or water (high-pressure cleaning).

Apart from the need for worker protection, it should be remembered that practically all solvents seriously pollute the environment. Particular problems in this regard include damage due to solvent evaporation, soil and groundwater pollution and the difficulties of disposing of used solvents and solvent sludges.

Foremost among modern methods of alleviating the problems of disposal are primary measures to prevent wastewater occurring in the first place, rather than subsequently treating highly contaminated bath and flushing water before it enters the drainage system. Membrane filtration and ion exchange processes can be used to regenerate process baths and extend their useful life. Similarly, flushing water can be used several times over with continuous dirt and oil separation (recycling via ion exchangers, emulsion cracking and cascade flushing techniques). Resulting wastewater quantities and pollutant loads are reduced. One might also attempt to process and reuse solvents in a closed solvent circuit. This technique is rarely successful in the case of reprocessing surfactants, so the improvement of their biodegradability is an important factor. Management should optimize selection of solvents based on technical and environmental factors11).

11) Only wastewater experts can definitively optimise the choice of solvents. Information is available in: Dagmar Minkwitz, "Ersatzstoffe fr Halogenkohlenwasserstoffe bei der

Entfettung und Reinigung in industriellen Prozessen" (serial publication of the *Bundesanstalt fr Arbeitsschutz* (German Federal Institute for Occupational Safety and Health) GA 38) Dortmund, Bremerhaven 1991 (Wirtschaftsverlag NW) ISBN-3-89429-086-2. See also "Zeitschrift Oberflchentechnik, Bezugsquellennachweis fr die Oberflchentechnik mit Trendbersichten und Tabellen, Munich, 4th edition 1991) (Seibt Verlag), ISBN 3-922948-70-7.

The following precautions should be taken where degreasing is carried out with organic solvents:

- **do not use substances which are unknown;**
- **use enclosed equipment where possible;**
- **ensure effective ventilation and aeration of work rooms;**
- **ensure good extraction at the workplace;**
- **avoid skin contact;**
- **use protective equipment;**
- **as solvents are heavier than air, they force the breathing air out of trenches, cellars, containers and depressions in the ground; suffocation can be avoided by means of floor openings and ventilation;**
- **use only non-combustible washing vessels with self-closing covers for cleaning small parts with inflammable solvents;**
- **keep only quantities of flammable solvents at the workplace as are required for the work and store in suitable containers with effectively sealed covers;**

- avoid electrostatic charges;
- in operating manuals indicate the solvents used, limitations on use and safety precautions, instruct personnel;
- secure and lock installations when not in use;
- avoid hand-spraying of degreasing agents with spray guns;
- avoid blow-drying with compressed air of surfaces which have been treated with chlorinated solvents;
- with open degreasing equipment, note the quantities of solvent displaced on immersion of the workpiece and dimension the system accordingly;
- workpieces should leave the system free of solvents.

2.1.3 Painting

Most spray paints and brush paints contain considerable quantities of hydrocarbon and chlorinated hydrocarbon solvents (spray paints as much as 90%, normally 50 - 70%) which evaporate on spraying and drying. Paints also contain finely dispersed pigments. Some of these are highly toxic. Depending on the application, paints may have to satisfy a wide range of quality requirements. Available paint systems are accordingly diverse.

There are three possible ways of avoiding solvent emissions from painting installations; these can be used separately or in combination:

- use of low-solvent paints

"High solids" paints, water soluble paints and dispersion paints have been developed for this purpose. A further alternative is solvent-free powder paint, for which new applications are constantly being found.

- **use of high-performance application methods**

Solvent emissions depend not only on the paint formulation but also on the application method. An important evaluation criterion is the application efficiency factor, which is defined as the ratio of paint remaining on the product to the total quantity of paint used. Lower efficiency means higher paint consumption and thus higher solvent emission. Application efficiency is primarily determined by the process and by the form of the parts to be painted.

The following application efficiency values can be taken as guidelines for the painting of large surface areas by various methods:

- **compressed air spraying 65%**
- **"airless" spraying 80%**
- **powder painting 98% (with recycling of spraying loss)**
- **electrostatic spraying 95%**
- **dipping, flooding 90%**
- **rolling, pouring approx. 100%**
- **brush, roller application 98%**

The choice of application method depends on certain quality requirements, e.g. coating thickness, surface roughness etc. and is hence closely related to the purpose of the painted object.

The various levels of waste gas resulting from the different methods can be greatly reduced by enclosing the application zone and additionally by air circulation. This will reduce the outlay on waste gas cleaning.

- **collection and cleaning of waste gas (with solvent recycling).**

2.1.4 Electroplating

To obtain different surface properties (surface refining), workpieces are electroplated with chromium, zinc, tin, copper, cadmium, lead or brass. For this the selected metallic coating is deposited from an electrolyte solution in an electro-chemical process. To enable the metal coatings to be applied, workpieces must be cleaned and degreased.

Where cold cleaning and degreasing are carried out, the hazards from cold cleaners must be taken into account (see 2.1.2). The boil-off technique is also used for rough cleaning. Strong alkalines such as sodium or potassium hydroxide solutions are used for this purpose. These alkalines can damage eyes, skin and respiratory tracts if splashed or given off as mist or dust. An electrolytic process is often used for subsequent fine cleaning. Electrolytes are often alkaline solutions (5% sodium hydroxide solution) or cyanidic salts. Apart from the dangers

posed by the boil-off technique, extraction ventilation is necessary in view of the large quantities of hydrogen produced, so as to avoid reaching the explosibility limit of the air-hydrogen mixture. Safety in the workplace is increased by installing gas warning devices.

Pickling degreasers and pickles are used to remove oxidation layers and casting or rolling scale from metal surfaces. These are acids (sodium hydroxide solution for aluminium) such as sulphuric, hydrochloric, phosphoric, hydrofluoric or nitric acid which attack and dissolve the workpiece surface. The main health hazards are skin diseases; dangerous vapours and gases can be inhaled in the case of inadequate extraction. Especially dangerous are nitrous gases which can occur when using nitric acids, also fluorine compounds from hydrofluoric acid and hydrogen chloride from hydrochloric acid.

Cyanides are used for cleaning in salt baths (fluorides), pickling (removal of thin surface films), with chemical and electrolytic polishing or burnishing, and also with surface coating and thermo-chemical hardening processes. These can cause hydrocyanic poisoning as well as skin diseases when solutions containing cyanide come into contact with acids. Therefore baths containing acids and cyanide must be covered and separated by partitions. Containers and equipment are to be clearly marked to prevent carry-over of substances which can mutually react. In all cases one should check to determine whether cyanide can be replaced by substances less hazardous to health.

The actual electroplating of the workpiece can be done in countless different process

variants and stages. Materials posing just about every conceivable danger can be used in electroplating. The dangerous properties result both from the main components of the bath fluid and from different additives such as emulsifiers, foam inhibitors and wetting agents.

Strong aerosols can occur during bath filling and further preparation. Dangerous substances may enter the breathing air due to the production of gas (hydrogen) during the electrolytic process.

The main hazards with coatings are skin complaints and in particular allergies due to nickel and chromates. If consumed, both nickel and chromates can be carcinogenic. Nickel in fluid particle form is subject to a TRK value12) 4 of 0.05 mg/m breathing air.

12) TRK value: German technical directive on concentration of carcinogenic substances

2.1.5 Welding

Welding is the joining of materials using heat and/or force, with or without the use of welding fillers (anti-oxidation substances).

The individual processes most commonly used are gas welding, arc welding and inert gas shielded welding.

Polluting factors in welding workshops are:

- chemicals in the generated gases, vapours and dusts
- high temperatures (approx. 3,200C - 10,000C)
- radiation (ultraviolet radiation): eye damage, severe inflammation of unprotected skin;

infrared radiation: can penetrate the vitreous body of the eye, reaching the retina and causing cataracts)

- noise (up to 110 dB(A))

Diverse hazards occur depending on the fuels, inert gases, filler materials, workpiece coatings etc. in use. The following table summarizes the pollutants occurring with the different welding methods. The carcinogenic and mutagenic elements chrome and nickel are especially relevant. Certain hazardous elements are detectable in welding fumes in concentrations of over 1% and can lead to health damage. Clinical and epidemiological investigations indicate a frequent occurrence amongst welders of chronic bronchitis and increased impairment of the respiratory tracts.

Pollutants occurring in various welding processes include:

Pollutant	Causes	Welding process	MAK * mg/m^3

Lead	PbO	Welding of lead or lead-coated workpieces	all	0.1
Chromium	Cr_2/ 3	Welding with alloyed electrodes, Cr Ni steel	all	
Cadmium	CdO	Cadmium-coated workpieces	all	0.05
Carbon monoxide	CO	Welding with basic coated electrodes, gas flame	all	30
Carbon dioxide	CO_2	Gas welding with coated electrodes, inert gas	all	5000
Copper	CuO	Welding of copper, copper-coated workpieces	all	0.1
Manganese	Mn O	Welding of workpieces containing Mn, all electrodes	all	5
Nickel	NiO	Welding of Cr Ni steel,	all	

		alloyed electrodes		
Nitrogen	NO_2	Welding in confined spaces, trenches, tanks	all	9
Zinc	ZnO	Welding of zinc, galvanized workpieces, zinc paint	all	5
Aluminium	Al_2O_3	Welding of aluminium, almost all types of electrodes	Arc welding	-
Iron	Fe_2O_3	Welding of steels, all electrodes	Plasma arc welding	8
Fluorides	F	Welding with basic and alloyed electrodes	Arc welding	2.5
Calcium	CaO	Welding with coated electrodes	Arc welding	5
Sodium	Na_2 OH	Welding with coated electrodes	Arc welding	2
Oxygen (ozone)	O_3	Strong UV radiation	Plasma arc welding	0.2

Titanium	TiO_2	Welding with coated electrodes	Arc welding	8
Vanadium	V_2O_3	Welding workpieces containing vanadium	Arc welding	0.5

*** MAK: maximum allowable concentration**

The welding of metals with anti-corrosion coatings may also have adverse toxicological consequences. Pollutants may be released depending on the type of coating.

Alkyl resins: acrolein, butyric acid
Phenolic resins: phenols, formaldehyde
Polyurethane: isocyanates, hydrogen cyanide
Epoxy resins: phenols, formaldehyde, hydrogen cyanide.

Although the inert gases carbon dioxide, argon and helium are not toxic, in poorly ventilated rooms they can displace the breathing air and under extreme conditions cause suffocation. Ozone may be produced during arc welding. Even low concentrations (0.1 parts per million (ppm)) of ozone can cause irritation to the eyes and upper respiratory tracts and in the event of exposure to 5-10 ppm over several minutes, pulmonary oedema.

At high temperatures nitrogen oxides are formed and emitted from the nitrogen and oxygen

in the air on the periphery of the welding flame. Nitrogen oxides are highly toxic and, after a relatively long asymptomatic period, can lead to radical lung changes, pulmonary oedema and death. If the workpiece has been degreased with solvents containing chlorine and not properly dried, phosgene may be produced during welding. Phosgene is highly toxic and can also cause pulmonary oedema after a long asymptomatic period.

Since the welding of plastics is not yet widespread in many countries, it is not dealt with here. It must be pointed out however that the hazards for man and the environment are also considerable with the welding of plastics. Protective measures and special disposal procedures are necessary to guard against the release of solvents and other waste gases containing pollutants.

2.1.6 Soldering

Soldering is the thermal joining of two materials using a material (solder) whose melting point is below that of the workpiece.

If the solder melts above 450C the process is termed "hard soldering or brazing" and at lower temperatures "soft soldering". Apart from additional hazards due to the base material binders, the hazards involved in soldering are mainly associated with the flux and the solder.

The composition of a flux depends on the base material, the solder and the intended use. More than 300 different types of flux are currently available, all of which contain aggressive

chemicals. Soldering paste usually contains colophonium, talc and salmiac, while soldering fluid contains zinc chloride or tin chloride. Chlorine and chlorine compounds cause irritation of the respiratory tracts and the skin and, in high concentrations, lung damage. Fluxes also frequently contain fluorine compounds (irritation of the respiratory tracts, burns). Fluxes often contain substances responsible for allergies. These are mainly colophonium and hydrazine. Hydrazine is additionally classed as carcinogenic.

Tin-based solders containing lead are used for soft soldering and silver solder containing cadmium for hard soldering. Flux vapours carry metal particles which can be inhaled.

Environmental protection measures to combat the emission of liberated gases and component substances of solders and fluxes include the installation of extractor systems with downstream separator filters (cyclone method). This method may also be used to contain the environmental impact of the production stage discussed in the next section.

2.1.7 Grinding

Grinding is the cutting of a workpiece with a geometrically undefined cutting process.

Grinding processes are characterised by high temperatures, workpiece removal and abrasive wear. In addition to noise, the health hazards from grinding are principally emissions from abraded dust or particles from the abrasive tool, workpiece and any coating, and - in the case of wet grinding - from coolants. There is an attendant risk of health disorders especially

affecting the skin and respiratory tracts. Additives in coolants and the metal dusts produced (e.g. from chromium, cobalt, nickel or beryllium) can result in allergies. These metals may also be carcinogenic. The following table shows the potential pollutant sources when grinding metals.

Potential pollutant sources in the grinding of metals

Material-dependent Process-dependent

Grinding tool Formation of superfine dust with

- **abrasive material - profiling and dressing of containing zircon grinding discs**
- **lead chloride, antimony - tool grinding sulphide in separating - fettling, due to adhering cutting in stationary operation mould residues**
- **additives in grinding - manual grinding, usually belts containing fluorine carried out without extraction ventilation**

Coolant - coarse grinding additives, with respect to - use of magnesite binders toxicity, carcinogenicity and mutual reactivity

Material containing Combustion and pyrolysis

- **more than 80% %/wt. products which can occur nickel (e.g. depositing with the**

thermal decomposition of materials) rubber or synthetic resin
- less than 80% %/wt. nickel (e.g. high grade corrosion-resistant steel)
- Lead (e.g. in automatic Accumulation of heavy metals and steel) superfine particles in coolant
- Cobalt (e.g. hard metal, co- due to inadequate filtration alloys) or overuse
- Beryllium (e.g. Ni Be alloys)

Atomization of coolant and thus also of additives, reaction products, dissolved heavy metals and superfine, non-separated particles.

Protective measures include environment-oriented selection of grinding tools, coolant and - where possible - materials, extraction of the abraded materials and personal breathing and hearing protection.

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2.2 Mechanical engineering and operation of workshops and shipyards

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Special environmental problems which are not found elsewhere arise in mechanical engineering, in workshops and in shipyards. This is because the work is not carried out in one location alone, and because pollutants are diffused and vaporised throughout the site. Estimation of their environmental relevance is difficult due to their often low concentration and they frequently seem harmless, so it is not easy to communicate the problem to workers and managers. Therefore environmental training measures should be taken into account as early as the planning phase. Much depends on the attitude in the workplace, the choice of working equipment and materials and the observance of worker protection measures. Planning must additionally include early integration of technical environmental protection measures (filter systems, wastewater collection installations, cleaning installations etc.).

2.2.1 Waste air

Environmentally relevant waste air flows can be released into the environment through forced ventilation (e.g. fan systems) and/or random emission13) from diverse areas of the site.

13) Emissions are defined as air impurities (gases, dusts), noise, radiation (heat, radioactivity etc.), vibration and similar phenomena given off to the environment by a (fixed or mobile) system.

These include emissions from:

- production extractor systems
- workplace extractor systems
- room air extraction
- production processes
- mechanical cutting
- thermal joining and parting (welding, cutting)
- joining (e.g. bonding, soldering)
- surface treatment (cleaning, coating, hardening and tempering)
- drying

Emissions into the air can be divided into:

- coarse and fine dust
- aerosols
- organic and inorganic gases and vapours

Harmful components of the waste air are essentially:

- organic solvents and halogenated hydrocarbons from metal cutting (coolants), cleaning, degreasing, bonding and painting of workpieces in the form of gases, vapours and aerosols

- dusts from the mechanical processing of materials

Whether or not cleaning of the waste air is an absolute necessity depends e.g. on the solvents in use, the presence of other contaminating operations, weather conditions etc., also therefore on ambient factors. Long-term risks for man and the environment may be posed even by relatively small workshops.

In the interests of worker protection, room air pollutants occurring in the production process must not exceed certain MAK values14). Where necessary work should be carried out in enclosed equipment. Efficient aeration and ventilation must be guaranteed, or pollutants must be extracted at the point of origin. Extracted flows of (pollutant) substances are to be cleaned by suitable processes before being expelled to the environment.

14) in Germany

Possible processes are:

Dust separation:

Dust is a mixture of particles of different grain size, particle size depending very much on the process. Various processes are used for dust separation. These are classified as follows:

A: inertia separators (cyclone, "multiclone", mechanical separator)

B: wet type separators (scrubbers, wet separators)
C: electrical separators (dry and wet electrostatic filters)
D: filtering separators (fabric filters, cloth filters, bag filters, vibratory sheet filters and tubular filters).

Aerosol separation:

Waste gases containing droplets are also termed aerosols and hence distinguished from dust-laden waste gases. Droplets can be separated using the same physical principles as for dust. The greater adhesion of the separated droplets compared with dust however rules out use of the principal dust separators such as electrostatic filters and filtering separators. Only wet separators, i.e. scrubbers and wet type electrostatic filters are suitable without modification for separating aerosols.

Separation of vaporous or gaseous substances:

The principal methods for reducing emissions of gaseous inorganic and organic substances are absorption, adsorption and thermal processes. With absorption the gaseous air pollutant is absorbed by a washing fluid. Absorption is either physical or chemical, depending on whether the absorption is based exclusively on the solubility of the gas, or whether additional chemical reactions occur in the liquid phase. Absorption processes, and also thermal and catalytic processes, are used particularly for reducing levels of organic substances.

Water-soluble organic substances, e.g. methanol, ethanol, isopropanol and acetone can be effectively separated from waste gases through absorption by means of scrubbers. The contaminated washing fluid can normally be regenerated by fractionation15).

15) Fractionation is the separation of fluid mixtures by repeated distillation.

Separation of large amounts of solvents is done by the condensation process. Recently, biological processes such as biofilters or biowashers have also become popular for cleaning waste gases with highly odorous components and/or solvents.

Adsorption is the attachment or accumulation of foreign molecules on the surface of a solid (adsorbent). Regeneration of laden adsorbents is normally done by desorption of the adsorbed substances in the gas or liquid phase (so-called desorption phase), i.e. by reversal of the adsorption process. As the desorption phase (usually a gas) contains the substance removed from the waste gas in an enriched concentration, recycling or reprocessing is possible. Solvent recycling is an especially important area of application for the adsorption process. Adsorbents are mostly activated carbons.

The residual substances yielded by the separation of the solid and gaseous waste gas pollutants (filter dusts, scrubbing water residues etc.) are normally hazardous materials and must be disposed of as special waste (giving rise to waste problems). The price of solving emission problems is often soil and water contamination, and land may become so

contaminated it will eventually have to be rehabilitated (see also the environmental brief Disposal of Hazardous Waste).

2.2.2 Wastewater

In mechanical engineering, the recycling of process materials from wastewater is frequently only possible with disproportionate technical effort or not at all, because of the low concentrations involved. Concentrated liquid and spent process and production materials can and must be collected and disposed of as (hazardous) waste.

Wastewater is returned to natural bodies of water (lakes, streams, rivers, sea) after preliminary and final cleaning. There, any inorganic pollutants will lead to poisoning and deposits. Organic impurities may also be toxic and/or non-degradable. Degradable, non-toxic waste substances damage the environment by initiating excessive growth (eutrophication) of bacteria and minute life forms (algae, fungi) due to the nutrient supply. In combination with cell metabolism, this results in high oxygen consumption and finally to phenomena such as the "overturning" of the water (anoxic waters).

Heavy metals mostly enter the wastewater as metal salts produced by chemical reaction of the metals with the acids. The acidic pH value which prevails in heat treating and pickling shops promotes the solubility of the heavy metals in wastewater and hinders their removal.

Heat treating and pickling shops rinse workpieces in fresh water prior to further processes.

After use, pickling fluids also contain heavy metals. In electroplating operations, rinsing water contains cyanide and is polluted with the heavy metals which are used (depending on the type of surface finishing).

Halogenated hydrocarbons are insoluble in water. They mainly enter the wastewater via rinsing water after degreasing in surface treatment plants and when cleaning engines and other objects in motor vehicle and general workshops by the use of cold cleaners and pickling agents. Further emission sources are coolant carry-overs and losses, workpiece rinsing and workshop floor cleaning.

Organic solvents can enter the wastewater via absorption and spray cleaning processes. Mineral oils occur with the cleaning of workpieces and floors and degreasing, and through losses during processing. Emission sources are repair, motor vehicle, factory and maintenance workshops. In surface treatment workshops they occur in the form of the workpiece anti-corrosion and rust-protection oils used in preliminary cleaning.

Acids and alkalis enter the wastewater in pickling shops and heat treatment shops in connection with degreasing. Other wastewater burdens occur due to nitrogen (ammonium) and phosphor compounds (phosphates from pickling shops).

Wastewater can be cleaned by chemical, physical and biological processes or a combination of these. Three-stage purification of industrial wastewater is now generally considered the state of the art.

Only organic and non-toxic wastewater impurities can be removed biologically. Tests in the laboratory will determine whether or not the components contained in the wastewater inhibit biodegradability.

With biological processes a distinction is made between aerobes (with oxygen) and anaerobes (without oxygen). With high burdens (chemical oxygen demand (COD) in excess of 15,000 mg/l), anaerobic processes are used for preliminary cleaning before aerobes carry out the final cleaning, since otherwise the oxygen supply costs are excessive.

High-performance biological processes with high pollutant decomposition rates are now available to build small but nevertheless efficient systems. Newly developed processes are achieving success in the biological neutralisation of organic pollutants previously considered non-biodegradable, e.g. CHCs, by optimising the living conditions for special bacteria.

Flocculation/precipitation processes can be used to remove heavy metals from wastewater, also sedimentation processes in the case of undissolved wastewater. Chemical oxidation and precipitation processes can be used for the removal and de-toxification of cyanide.

Emulsions originating from the use of coolants can be separated by the membrane filtration process in conductive wastewater (approx. 90%) and concentrate.

Ultrafiltration is used with electrostatic immersion painting for the separation of solid paint residues. This is increasingly replacing simple sedimentation with the separation of

undissolved pollutants in wastewater because it is more efficient, though more costly. Wastewater containing acids and alkalines must pass through neutralization systems. Ion exchange systems cannot selectively remove metals but are highly suitable for cleaning water carried in a circuit and recycling raw materials. For recycling pure raw materials, the different waters must be carried and used separately.

2.2.3 Waste matter

Waste matters generated by these plants can be divided into three groups:

A. Residues of the used raw materials. These include both ferrous and non-ferrous (NF) waste (scrap/chips and swarf) which may be highly contaminated with coolant, cutting oil and leaked lubricating oil.

B. Waste from process residues resulting from the processing of semifinished products and auxiliary materials. Metalliferous residues are e.g. burnt slag from torch cutting, metal sludges, used salt and acid baths from electroplating or pickling shops.

C. Non-metalliferous waste can be paint and adhesive residues, oil and oily waste, organic acids, alkalis and concentrates. Finally, waste may also be produced by wastewater and waste air cleaning processes. These include purification sludges from the works’ own sewage treatment plant plus dusts and sludges from the cleaning of waste air and extraction flows in the form of filter residues.

Nearly all waste in the second and third groups can be regarded as hazardous waste. They demand special monitoring and special disposal methods. Waste from the first group should mostly be recycled. Separate collection of scrap types (structural steel, alloyed steel, NF metals) in different containers is important for simple and comprehensive recycling.

In order to reduce scrap quantities with torch cutting and punching, care must be taken to achieve a systematic geometrical arrangement of contours on the sheet metal. Recycling should be considered where there are high concentrations of costly raw materials in liquid or sludge waste. To reduce waste further, fluids should where possible be cleaned with filters or baths regenerated.

2.2.4 Soil

The effects on the soil can be problematic in terms of both quality (e.g. toxicity or persistence) and quantity (e.g. acidification or leaching). Airborne emissions are normally small in quantity, therefore the main causes of pollution are the discharging of residual and waste materials (filter dusts, washer and scrubber residues, purification sludges) and improper handling of auxiliary materials. Of the large number of chemical substances used in metal processing, only a few substance groups have to be regarded as representing a soil hazard and thus in general also a groundwater hazard:

- **anions (chlorides, sulphates, ammonium, nitrates, cyanides etc., produced e.g. in heat treatment and pickling shops)**

- heavy metals (lead, cadmium, chromium, copper, nickel, zinc, tin etc.).
- solvents (halogenated and pure hydrocarbons)
- other oil-containing substances

The areas in which contamination occur are:

- all production stages using the named substances
- storage of new and used chemicals
- transport, loading and unloading on the works site (containers, tanks, pipelines, extraction system)
- cleaning and repair processes.

To protect against contamination in these areas, the ground must be "sealed" (i.e. provided with a protective layer to prevent penetration of the materials into the ground, or with pollutant collection devices, e.g. containment basins). Insufficient attention is often paid to the storage of hazardous materials. This can result in severe environmental pollution with long term consequences, also and in particular for third parties (e.g. due to groundwater pollution). Containers and pipelines used for transporting the materials are to be regularly checked for leaks. Care must be taken to ensure an efficient flow of work and materials, with clear rules on the depositing and disposal of waste/residues (see environmental brief Disposal of Hazardous Waste, also the reference literature).

2.2.5 Noise

Deafness and loss of productivity result from noise pollution above a certain level. A noise level in the workplace of around 85 dB(A) or higher for the greater part of the working shift, over a number of years, is regarded as detrimental to hearing16).

16) It is as harmful to be exposed constantly to a uniformly low noise level as to a higher one for a short time.

For comparison: Leaves blown by a light wind emit a noise level of 25 to 35 dB(A); normal conversation is between 40 and 60 dB(A). Note also that the medium and higher frequencies between 1,000 and 6,000 Hz are the most damaging.

When considering noise immissions17), a distinction must be made between the direct effect on workers at the workplace and the indirect effect due to radiation and immission in the environment. In assessing noise therefore, three aspects, each requiring different reduction measures must be considered.

17) The term immission is the effect of air impurities, radiation (e.g. thermal radiation) on man, animals, plants and property.

A. Noise origination
B. Noise propagation

Noise transmission (propagation of sound waves in different media, e.g. transmission of machine vibrations to foundations);

Noise radiation (stimulation of air vibrations by solid-body vibrations - loudspeaker diaphragm principle).

During operations in this sector, noise is generated by machinery, by hammering, nailing, or chipping, by internal transportation processes, impact upon depositing or lifting of semifinished products, air and gas movements, fan outlets, pneumatic components, cutting torches etc.

A fan, e.g. with 50 kW, 970 rpm and a diameter of 1,800 mm, without noise damping produces a noise level of 100 dB(A). A compressed air jet produces a noise level of 108 dB(A) with an air pressure of 5 atmospheres. Welding and cutting generate noise levels of up to 101 dB(A) and pneumatic riveters and chippers produce between 100 and 130 dB(A). Manual grinders develop up to 106 dB(A). Metal band saws develop up to 106 dB(A). Turning generates between 80 and 107 dB(A). Screw presses produce noise levels up to 103 dB(A).

Noise pollution in the neighbourhood of a factory is mainly caused by radiation through the walls of the production sheds and buildings and by outward blowing fans.

Structural measures to reduce noise should therefore be taken into account as early as the planning phase (noise-absorbing walls, choice of windows, type of building materials etc.).

The expected noise conditions cannot be determined simply by adding together the known noise levels of the planned machines and processes. Due to interaction and the different damping and reflection circumstances, only on-site measurements can yield accurate data on noise conditions. The maintenance of adequate distances reduces the effect on the neighbourhood.

With regard to noise protection, a distinction is made between primary and secondary measures. Active primary measures signify the use of machines constructed according to low-noise principles. For example, sheet metal forming can be made quieter by replacing impact methods with hydraulic pressing. Priority should be given to the implementation of active primary measures.

Active secondary measures are sound insulation (prevention of propagation by obstacles) and sound absorption (absorption of sound energy and its conversion to heat). A distinction is made between structure-borne and airborne noise:

- **Insulation of airborne noise is achieved by partition walls, full or partial enclosure, cladding or screening.**
- **Insulation of structure-borne noise can be achieved by machine feet of elastic material which prevent the transfer of vibrations.**
- **Absorption of airborne noise over large areas can be achieved with sound-absorbing cladding material of foam or glass fibre matting. Silencers should be**

fitted to reduce noise at gas and air outlets. Composite silencers combining an absorber and a resonator should be provided for dust-laden gases.

- Absorption of structure-borne noise damping is achieved by means of soundproof coverings in the form of foam rubber mats on sheet metal or in sandwich form (metal - covering - metal).

Passive noise protection signifies all equipment and measures for preventing the immission of noise and vibration to the environment and the human ear. These include personal ear protection, noise protection for control rooms, noise-insulated cabins etc.

Workers must wear ear protection in the workplace where noise levels are higher than 90 dB(A). Such workplaces must display suitable warning signs; the observance of protective measures must be monitored.

Proven methods of reducing noise immissions include the use of soundproof walls or partitions and increasing the distance between industrial buildings and residential areas. With uninhibited propagation the acoustic power level is reduced by 3 (house wall) or 6 (point source of noise) dB(A) by doubling the distance.

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3. Notes on the analysis and evaluation of environmental impacts

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This section describes underlying reference material which, unless otherwise indicated, refers to the situation prevailing in Germany. Obviously these rules cannot be applied wholesale to other countries without modification. The material is intended at least to serve as a reference where no national regulations are available. The INFOTERRA National Focus Points of the UNEP are a valuable source of information. These contain environmental information records for the member state in question. The reference service is free of charge. The Environmental Guidelines of the World Bank are an important source of application-related information, e.g. for dust emissions, waste matter and wastewater.

The Catalogue of Environmental Standards (Vol. III of this Environmental Handbook) also deserves special mention. This lists standards and limits for assessment purposes.

Regulations on the protection of persons from danger and injury in the workplace (worker safety, industrial medicine) are contained in the *Unfallverhtungsvorschriften der Berufsgenossenschaften* (accident prevention regulations of the employers' liability insurance associations) and in their other publications such as *"Sicherheitsregeln"* (safety regulations) and *"Richtlinien"* (guidelines). Also worthy of note are the Occupational Health and Safety Guidelines of the World Bank and the Encyclopedia of Occupational Health and

Safety of the International Labour Organisation (ILO).

3.1 Air

TA-Luft (Technical Instructions on Air Quality Control) regulates the technical standards concerning pollutant emissions and immissions for installations subject to licensing.

The guidelines on maximum immission concentrations (MIK) published by the Association of German Engineers (VDI) lay down limits for certain air pollution levels. These are defined as the concentrations in the ground-level open-air atmosphere or in dust and the quantities precipitated on the land below which man, animals, plants and property are guaranteed to be safe according to the present level of scientific knowledge (see also reference to MAK values).

Also of importance are the EC Directives on sulphur dioxide and suspended particulates, lead and nitrogen dioxide (EC Directives 80/779/EWG, 82/884/EWG, 85/203/EWG), also the WHO Air Quality Guidelines for 28 chemicals on the basis of toxicological findings.

3.2 Wastewater

Discharge conditions for wastewater are laid down in the *Wasserhaushaltsgesetz* (Federal Water Act), the *Abwasserangabengesetz* (Wastewater Charges Act) and the associated *Verwaltungsvorschriften* (administrative regulations). These prescribe limits of individual

pollutants for different sectors.

Annex 40 currently applies to metalworking and processing with direct discharge (discharge into bodies of water). This gives details of the maximum concentrations for COD18), BOD19), heavy metals, hydrocarbons, ammonium, phosphorous and halogenated hydrocarbons.

18) COD: Chemical Oxygen Demand
19) BOD: Biological Oxygen Demand

The limits for indirect discharge (discharge into waste-water purification plants) for COD and substances classified as non-hazardous are less strict. The limits for indirect discharge are detailed in the ATV work sheet *Arbeitsblatt A 115* according to sectors. This work sheet is currently being adapted to the new wastewater management regulations.

For their projects the World Bank stipulates that the temperature of discharged wastewater must be no more than 3C higher than that of the receiving body of water. If the temperature of the receiving body is 28C or less, the temperature of the discharged wastewater must be no more than 5C above that of the receiving water.

3.3 Waste matter

The definition of waste types according to Section 2 of the *Abfallgesetz* (Waste Avoidance

and Waste Management Act) for the metal working and processing industry is contained in the *Verordnung zur Bestimmung von Abfllen* (Regulation on Waste Definition). A further designation of waste types according to code numbers is contained in the publication on waste types of the German state working group on waste *Landesarbeitsgemeinschaft Abfall (LAGA).* Of relevance here are waste groups 35 (metal waste), 51 (oxides, hydroxides, salts) with electrolytic sludges, 52 (acids, alkalis, concentrates) with waste from surface treatment, 54 (mineral oil products) and 55 (organic solvents, paints, lacquers, adhesives, cements and resins). For electroplating and painting, refer to the regulation on waste identification *Abfallnachweis-Verordnung*. For motor vehicle and general workshops, see the regulation on waste oil *Altlverordnung*.

For the use and handling of special waste, refer to the three-volume edition of "The Safe Disposal of Hazardous Wastes" and the manual "Techniques for Assessing Industrial Hazards", both published by the World Bank; also the environmental brief Disposal of Hazardous Waste.

3.4 Noise

Accident prevention regulations are published by the employers' liability insurance associations or *Berufsgenossenschaften*, and these deal with the protection of workers from noise in the workplace. The noise protection and information sheets of the *Hauptverband der gewerblichen Berufsgenossenschaften*, are important publications in this regard. The

Association of German Engineers (VDI) has issued numerous regulations and directives concerning noise in the workplace, the impact of noise on the environment and noise protection measures. Guidelines on noise protection for installations subject to licensing (according to the implementing ordinance of the Federal Immission Control Act) and neighbourhood immission guidelines are contained in TA-Lrm (Technical Instructions on Noise Abatement).

4. Interaction with other sectors

Mechanical engineering and the production of semifinished products for machinery in other sectors represent a highly diversified capital goods industry, so there is often close interaction with other sectors. Interaction is not necessarily regional, on account of the high specific added value, therefore interacting environmental problems do not occur generally but rather in individual cases.

With mechanical engineering works, workshops and shipyards of a certain size, attention must be paid to the effects on infrastructural sectors. In this regard see the environmental briefs Spatial and Regional Planning, Planning of Locations for Trade and Industry, Overall Energy Planning, Water Framework Planning, Urban Water Supply, Rural Water Supply, Wastewater Disposal, Solid Waste Disposal, Transport and Traffic Planning, Road Building

and Maintenance - Building of Rural Roads, Road Traffic, Railways and Railway Operation, Inland Ports, Shipping on Inland Waterways, Ports and Harbours - Harbour Works and Operations, Shipping, River and Canal Engineering.

There may also be an interaction with sectors covered in the following environmental briefs Surface Mining, Underground Mining, Minerals - Handling and Processing, Power Transmission and Distribution, Iron and Steel and Non-ferrous Metals.

5. Summary assessment of environmental relevance

The aim of this environmental brief has been to summarize the environmental relevance of mechanical engineering works, workshops and shipyards. Detailed investigations are to be made in each specific case as to the possible environmental hazards. Even small environmental problems which appear at the outset to be of marginal importance can, in certain contexts, result in failed projects or serious damage. Countermeasures must be integrated into the planning and execution at an early stage. From the point of view of environmental protection, mechanical engineering should involve a combination of precautionary measures and appropriate management decisions. Therefore training in environmental protection must be given high priority in every project. Workers should be trained in occupational safety and environmental protection. The management should be

familiar with and apply additional precautionary measures (knowledge of suitable pollutant disposal methods or plant optimization with a view to environmental protection, e.g. choice of paints/solvents with low pollutant contents).

An important further precondition of applied environmental protection is the existence of effective waste disposal facilities, especially for problematic hazardous waste. Technical staff must also be on hand, e.g. to maintain filtration and wastewater treatment plants, the erecting and operation of which are described in the present brief.

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52. Agro-industry

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5. Summary assessment of environmental relevance

6. References

1. Scope

The agro-industry is based on agricultural and forestry production, and its purpose is to preserve and refine raw produce and to extract and concentrate the valuable constituents. The food industry constitutes the most important sector of the agro-industry.

Many agro-industries have developed from skilled manual production processes and accordingly can be carried out at varying technical levels. The following information, however, applies to small and medium-sized operations. The definition of small and medium-sized operations varies from country to country but a maximum of 100 employees can be taken as an upper limit. There are environmental briefs which focus specifically on a number of agro-industries, particularly large plants.

In no other area are development and environment so closely intertwined as in that of the agro-industry. Unforeseen implications can turn intended impacts on their head, and medium and long-term damage may prove to be of short-term benefit. Nowhere are effects on the biosphere -including human society - so all-embracing as in the agro-industry. And no

other sector is so dominated by female employment; all the activities in this sector are of major importance to and have major effects on women. All agro-industry activities depend essentially on the limited time women have available, their extensive responsibility and on limited water and energy resources. This is why the socio-economic parameters and influences are priority issues in agro-industry projects.

A distinction can be made within the agro-industry between primary, secondary and even tertiary processing. Primary processing is basically most suited to small industrial operations, as technical input increases in line with processing complexity.

2. Environmental impacts and protective measures

2.1 <u>The agro-industry generally</u>

As the agro-industry will probably increase the demand for certain commodities, or alternatively push towards different forms of land use and farming, the following environmental impacts in the area of agricultural production should be mentioned:

Problems relating to the direct expansion and intensification of resource usage include impairment of soil fertility, problems of soil losses and sedimentation, problems of desertification and irrigation problems (soil and water salination, fluctuating water table and

water pollution), which in turn reduce resource productivity. The problems of fertility losses, desertification, and salination are generally greatest in countries where the population pressure on land is greatest. Here, agriculture expands most markedly in peripheral areas and marginal resources are utilised intensively.

The most successful efforts lie in the promotion of soil-conservation measures: reducing the intensification of soil usage, and introducing programmes for minimum or soil-conservation farming (contour line farming, terrace farming, strip farming, extension of dry and green fallow land), programmes to control flooding and wind erosion and programmes for the improvement of crop rotation. What needs to be examined is the extent to which these measures should be implemented as an alternative or in addition to the establishment of agro-industrial production operations.

The economic and social parameters in place and those sought are decisive factors in the agro-industrial sector generally. The maintenance and promotion of subsistence production and agro-industrial activities without restricting subsistence are major axioms in this respect.

Commodity processing gives rise to environmental impacts on the atmosphere (odours and dust emissions), water (quantity and wastewater), primary energy sources (mainly timber) and the soil.

The following comments are confined to certain branches which have been in the greatest demand in recent years.

2.2 Selected branches

2.2.1 Mills handling cereal crops

Only dry milling is carried out in such plants, thus account must be taken of noise and dust emissions which affect not only the specific operational area but also the area surrounding the mill. Suitable countermeasures are technical installations (extraction, soundproofing) and individual measures (breathing apparatus, hearing protection), priority being given to the first group, since the use of individual safety equipment requires explanatory and supervisory measures.

Surface water quality is impaired in cases where streams and rivers are used for waste disposal, for example. Further usage or controlled dumping are suitable countermeasures (cf. environmental brief Mills Handling Cereal Crops).

2.2.2 Processing of starch sources and root crops

If the biologically polluted wastewater from washing and processing is discharged into surface water untreated, the result can be overfertilization, reduction in the oxygen content and therefore a general impairment of water quality, changes in the micro flora and fauna and, in the medium term, disruption of water biotopes.

Appropriate minimum measures are mechanical separators and aeration ponds in which the

biological oxygen demand is reduced to an acceptable level. Since a reduction in the biological pollution of wastewater is associated with improved yield, optimised process technology can also be an economically beneficial environmental measure. Finally, highly polluted wastewater which can normally be avoided where a process is appropriately optimised, can be used as a substrate for biogas production.

2.2.3 Processing of oil-bearing seeds and fruits

In small and medium-sized works, only pressing processes are used for oil extraction, with solvent extraction reserved for large plants (see also the environmental brief Oils and Fats). Oil-bearing fruits are heated directly or with steam or hot water to improve yields. This produces steam emissions and oil-laden wastewater. Wood is often used for energy production, and this can lead to over-use of tree stocks.

Because steam emissions affect mainly operating personnel extraction should take place at the point of production. Once again, process optimisation, the use of better separators and treatment in aeration ponds should be used to reduce wastewater pollution. Consumption of wood or other commercial fuels can be reduced by incinerating the waste produced in the processing operations and also by optimising energy circuits and consumption in the processing plant.

2.2.4 Sugar beet and sugar cane processing

The essential environmentally relevant aspect of beet and cane processing is the energy required for the concentration of the sugar solution. While this requirement can be met in cane processing by burning bagasse, energy consumption in sugar beet processing must be optimised and, if necessary, alternative energy sources must be identified.

Mention should also be made of organically polluted wastewater from purification and condensate.

There is an environmental brief specifically relating to Sugar.

2.2.5 Fruit and vegetable processing

Biologically polluted washing water and the energy requirement for thermal preservation processes are of environmental relevance in this area, and the same comments as in the previous sections apply. Solar driers can also be used, thereby reducing the energy required for the production of top quality dried products quite considerably.

2.2.6 Dairies

As milk and dairy products are ideal breeding grounds for microorganisms, hygiene requirements are relatively stringent, a factor which prompts the use of aggressive cleaning agents. If they are discharged at certain concentrations, the quality of surface water is impaired and micro flora and fauna are affected.

Countermeasures are the sparing use of biodegradable cleaning agents and dilution in tanks.

Mention should also be made of percolating milk in rinsing and washing water as a source of organic pollution.

2.2.7 Processing of semi-luxury goods and spices

The operations having the greatest environmental relevance in the production of semi-luxury goods and spices are fermentation and waste disposal. Fermentation is generally carried out in fixed locations, and the pollutants thereby produced can accumulate in the soil over long periods, damaging micro flora and fauna. The washing operations sometimes carried out after fermentation (e.g. coffee) give rise to biologically polluted wastewater which, if discharged untreated, can impair surface water quality. The impacts of this are restricted to harvest time, and are then found over longer intervals.

Fermentation should be carried out in the immediate vicinity of an abundant supply of running water at appropriately prepared places (cement bases). The heavily polluted wastewater produced must either be suitably diluted before discharge or used for biogas production. As washing water is not generally so heavily polluted, special measures (aeration ponds) are only required in exceptional cases. Spices are often irradiated as a method of preservation, although the consequences of irradiation on human health are as yet unknown.

2.2.8 Plant fibre extraction

In many countries, microbiological retting is practically the only method of plant fibre production in use. It involves the degradation of non-fibrous components by a microbiological process and is carried out by immersing the raw material either in a slow flow of water or in specially prepared tanks, whereupon the retting is spontaneously initiated. Since this process and the subsequent fibre washing require large quantities of water, these installations are always built close to abundant supplies of running water. In these circumstances, the water exchange required once the retting process is complete is no problem (except perhaps for any dissolving pesticides used during farming).

The retting process is associated with a certain odour nuisance which cannot be avoided at reasonable cost. The only remedy is not to site these plants close to residential areas and to take account of prevailing wind directions.

Because fibre production is a low-input technology in every respect, negative environmental effects can only be avoided by selecting a suitable site and making use of what nature has provided.

2.2.9 Tanneries

Of all the agro-industries tanneries harbour the greatest risk potential for the environment. This is due on the one hand to the considerable odour nuisance and on the other to the

dyes and other chemicals (particularly chromium compounds) used in the tanning process which complicate the wastewater treatment operation. And there is also biological pollution. Besides a substantial impairment of the quality of the nearby surface waters, an enrichment of the hazardous substances in the soil, and possibly also in the groundwater must also be expected.

The elimination of odours at source is only possible if the tanning is carried out in enclosed rooms and any air escaping is cleaned in technically sophisticated filter systems. The nuisance can be limited indirectly by concentrating plants of this kind on sites a suitable distance from residential areas. This would also create the conditions essential for the relatively complex process of multistage wastewater treatment, which is essential in this industry but which is really too costly for an individual small plant (see also the environmental guidelines of the World Bank).

2.3 Socio-economic impacts

The overwhelming majority of jobs in the agro-industry call for little in the way of qualifications and most workers are women. However, as mechanisation and machine-based jobs increase, the proportion of male workers rises - as do monotony and isolation of the individual working processes, and the risk of accidents. The extent to which the employment of women leads to changes in their own food production needs to be examined. The jobs are of poor quality in ergonomic terms, and nuisances in the form of dust, damp, smells and

noise may attain levels which can affect the health of employees, constituting a considerable risk to women in particular. Because different types of jobs are done by the two sexes, qualification and training programmes must be established at an early stage, with the emphasis on female employment. These programmes should take account of the overall form of production and lifestyle of female employees and their families.

3. Notes on the analysis and evaluation of environmental impacts

The environmental impacts in the agro-industry can be assessed in terms of space, time and in relation to various resources and employees.

In the "agro-industry" sector assessments are based directly or indirectly on the following test criteria:

- impacts on employees in the factory
- impacts on people living near the factory
- environmental changes due to the emissions from the factory
- environmental changes caused indirectly by the factory (e.g. change in the quantity of water or extra energy required).

Short-, medium- and long-term impacts and likewise direct and indirect impacts must be

considered in the light of these test criteria.

The evaluation involves comparing the project with other possible projects, and also considers the economic, ecological and social costs involved.

The evaluation of effects on health faces the problem of the frequent lack of national limits or recommended values for individual substances, and this is further complicated where a number of substances are emitted at the same time, thereby increasing their impact due to synergistic effects. One initial approach to this problem area may be provided by publications of international organisations such as the World Health Organisation (WHO) (see in this regard Volume III, Compendium of Environmental Standards.

4. Interaction with other sectors

There are close links with the plant and animal production sector which supplies the raw materials, and with the marketing sector, not forgetting the metal and mechanical engineering industries which manufacture the processing equipment, and the packaging materials industry.

Other factors in the equation are veterinary services, livestock farming, irrigation and health and nutrition. Projects in the field of the economy and also infrastructural measures,

particularly in the rural hydraulic engineering sector, are significant issues in the assessment of agro-industrial projects, while cross-sectoral concepts of general resource management, location planning and regional planning must not be forgotten.

5. Summary assessment of environmental relevance

Agro-industries often serve as pilot projects for more general industrialisation, and must therefore be examined very closely in terms of their direct and indirect impacts on the food supply and economic prospects of the country concerned, its general environmental conditions, and the lives of its female population in particular.

Agro-industrial projects are extremely important to a country's independent development and this is closely allied to general subsistence production.

Direct environmental pollution from small and medium-sized agro-industrial factories on an individual level is relatively slight in the short-term, but the more general effects can be quite considerable.

One exception to this is tanneries because of the chemicals used -which are problematic in environmental terms - and the odour nuisance.

All factories which use water as the extraction, cleaning and transport medium produce wastewater which is biologically polluted to varying degrees, and this generally requires treatment in aeration ponds or treatment plants. Noise and dust emissions are normally restricted in terms of the area affected, and therefore affect primarily the employees themselves.

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53. Slaughterhouses and meat processing

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Contents

1. Scope

This sector embraces slaughterhouses, meat-processing plants and animal carcass disposal plants.

To date no standard project types have gained prevalence for slaughterhouses, particularly in terms of size, as each project is dependent on a a number of factors, such as:

- **regional population density;**
- **specific consumption (kg/person and year);**
- **animal stocks in the region, catchment area;**
- **distance from nearest slaughterhouse;**
- **export potential, restrictions;**
- **eating habits;**
- **religious constraints.**

Nor is there a standard size of meat-processing plant, as their design is also influenced by these same factors.

Animal carcass disposal plants (ADP) process dead animals, confiscated carcasses (where the meat or organs of slaughtered animals is found to be unfit for human consumption), blood, bones etc., the end products of which are - depending on the raw material - technical fats and meat meal, bone meal, blood meal etc., used for fodder and in some cases as fertilizer. Project size is determined primarily by the capacity of the neighbouring slaughterhouse.

For reasons of hygiene, cattle are hung for slaughter. The slaughter line feed system is manual in small operations and mechanical in plants with a medium or large line capacity.

Different processes are used in the bleeding stage, for example, since animals must be hung for bleeding to comply with EC Guidelines, but laid flat ("bleeding with the neck pointing to Mecca") in accordance with the dictates of Islam. (Sheep and camel slaughter similar to cattle slaughter).

Pigs can be slaughtered either hung or lying. A number of processes have been developed for the scalding and skinning of pig carcasses (scalding tank and depilation machines, production line systems where the animals are suspended or laid flat) depending on line capacity. Ritual slaughter is carried out for export.

Sheep are hung for slaughter and a number of methods are used for bleeding.

Because of the large number of different meat and sausage products, a wide range of processing stages20) are required. However, the following can be regarded as basic operations for all products:

20) for the processing of raw products and by-products.

carcass splitting - grinding of meat - seasoning - filling of natural or synthetic skins with sausage meat - heat treatment - cooling - dispatch - long-life meat products - tinned food.

The various processes used in the manufacture of meat and sausage products depend on the particular meat and sausage products in question, with processing carried out within different temperature ranges:

- **uncooked sausage process temperature approx. 14 -28C**
- **cooked sausage process temperature approx. 50 - 80C**
- **tinned meat and sausage products process temperature approx. 80 -121C**

In animal carcass disposal plants, the material used and the waste material is largely processed by the pressing process following heating.

The extraction process is rarely used today because of the residues it leaves in the meal.

***Fig. 1* - Flow chart of slaughterhouse**

Fig. 2 - Flow chart of slaughter procedure

Fig. 3 - Flow chart of a meat product factory

Fig. 4 - Flow chart of ADP press installation

2. Environmental impacts and protective measures

Meat industry facilities cause environmental impacts due to:

- wastewater;
- spent air/waste gases;
- noise;
- animal waste;
- waste heat;
- residues in the end product;
- waste.

German regulations relating to environmental pollution caused by meat processing are taken as the reference in the following as they have also gained acceptance as the international standard.

***Table 1* - Environmental impacts from meat industry plants**

Type of plant	**Waste-water**	**Odour**	**Waste gases**	**Noise**	**Waste**	**Waste heat**
Fattening and breeding operations	**X**	**X**	**X**	**X**	**X**	
Slaughterhouses	**X**	**X**	**X**	**X**	**X**	**X**
Recycling plant	**X**	**X**	**X**	**X**		**X**
Meat-product factories	**X**	**X**	**X**	**X**	**X**	**X**

2.1 Water pollution

Water consumption and the degree of contamination of the wastewater arising from the process depend on a number of factors, and are determined principally by the following:

- **species of animal;**
- **type and capacity of plant;**
- **intensity of cleaning of carcasses and**
- **working accommodation during the process.**

The following values apply for slaughterhouses (average values):

- cattle 600 - 800 l/animal
- swine 300 - 500 l/animal
- sheep 200 - 300 l/animal.

Water consumption in meat-product factories is largely product dependent. Wastewater pollution is higher, for example, in plants producing mainly cooked sausage and tinned products than in those which, for example, produce only uncooked sausage (salami). Consumption is around 10 - 15 m^3 per tonne of sausage and meat products.

Water consumption in ADPs is relatively low. The quantity of wastewater produced depends on the quantity processed, as some 65% of the raw material must be evaporated. On average, the wastewater level is approximately 1 m^3/t raw material.

The degree of water pollution in the meat-processing industry is extremely high, particularly in slaughterhouses and ADPs. In Germany, the following minimum requirements on the discharge of dirt or wastewater into watercourses must be observed by the meat industry to prevent water pollution.

Table 2 - Degree of pollution of wastewater

Type	BOD$_5$ valuemg/l	Causes and factors of influence
Slaughterhouses	approx. 4,000	Some blood, content of stomach and intestinal tract, urine, liquid manure, animal waste etc.
Meat-product factories	approx. 10,000	Animal waste, type of processing (boiling and steaming of raw material and end product)
ADPs	approx. 10,000	Type and quality of the raw material

Table 3 **- Minimum requirements for wastewater disposal in water**

Type	**Matter which can be removed by settling$^{3)}$**	**BOD$_5^{1)}$**	**COD$^{2)\ 4)}$**
Slaughterhouses and meat-processing plants	< 0.3 ml/l	< 35 ml/l	< 160 ml/l
ADPs	< 0.5 ml/l	< 40 ml/l	< 30 ml/l

Key:

1) BOD_5 = Biochemical oxygen demand over a 5-day period, with oxygen consumption determined in this period (g O_2/l wastewater at T = 20C)

2) COD = Chemical oxygen demand in the reaction with $KMnO_4$ or K_2Cr_2O7 as the oxidation agent (mg O_2/l wastewater)

3) Random sample

4) 2hr mixed sample

Slaughter costs are increased because of increased investment costs and running costs for wastewater treatment in relatively expensive treatment plants. Consequently animals may be slaughtered outside instead of inside slaughterhouses and thus no comprehensive check on hygiene conditions can be guaranteed.

After eliminating solids by mechanical purification, pond systems or the seepage of wastewater into the ground can be considered a substitute for biological treatment systems, provided that this does not pollute the groundwater mains or groundwater collection installations used for the drinking water supply.

The following can help slaughterhouses and meat-product factories reduce their wastewater pollution and dispose of their effluent correctly:

- better understanding of environmental issues by personnel;
- installation of technical facilities for improved separation of blood from the wastewater system;
- removal of waste of coarser consistency from production area floors before wet cleaning;
- fitting of sludge buckets in floor drains;
- fitting of wastewater screens to separate solids from the wastewater (these solids have a high protein content and can be passed on to ADPs);
- installation of sludge trap and fat separator;
- flotation plants (mechanical flotation treatment);
- supplementary biological clarification as a second treatment stage following mechanical treatment in plants which discharge their wastewater directly into surface water.

Wastewater from ADPs has to be sterilised.

2.2 Air pollution

Emissions occur primarily in the form of air discharged from the following areas:

Table 4 - Emissions from outgoing air

Type	Source area

Slaughterhouses	Stalling, possibly also storage, confiscated meat
Meat-product factories	Processing, smoke (cooking plant)
ADPs	Delivery, processing

To reduce the smell nuisance, slaughterhouses in Germany must, wherever possible, be sited at a distance of at least approx. 350 m from the nearest residential building.

Odours arise due to the odour of the animals themselves and changes to organic materials. As all smells arising in slaughterhouses are biodegradable, bio-scrubbers and biofilters can be used to reduce smells, as can adsorption and absorption processes.

***Table 5* - Immission values (IVs) (*TA-Luft* [Technical Instructions on Air Quality Control])**

Pollutant	**IV 1 continuous operation**	**IV 2**
Airborne dust (regardless of dust content)	0.15	0.30 mg/m3
Lead and inorganic lead compounds as	2.0	- g/m^3

components of airborne dust - expressed as Pb - Cadmium and inorganic cadmium compounds as components of airborne dust - expressed as Cd - Chlorine Hydrogen chloride - expressed as Cl -Carbon monoxide Sulphur dioxide Nitrogen dioxide	0.04 10.0 0.10 10 0.14 0.08	- g/m^3 0.30 mg/m^3 0.20 mg/m^3 30.00 mg/m^3 0.40 mg/m^3 0.20 mg/m^3

Waste gas from meat-product factories can be treated in a number of ways, including:

- **post-combustion;**
- **condensation;**
- **absorption - adsorption;**

- electrical separators for particulate substances in conjunction with the above processes.

The emission reference value is the total carbon in the organic compounds.

In new continuously operating plants, emission values can be contained with technical installations so that:

- the established immission values (see Table 5) are not exceeded, and
- as experience has shown, no odour nuisance occurs where the chimney is of the correct height for gas disposal.

The installation of ventilation and air-extraction systems, waste gas systems etc. incurs high investment costs and this in turn can lead to high slaughterhouse fees which users cannot afford.

The following values are recommended to reduce substances which cause odours in ADPs:

- thermal post-combustion: 20 mg/m^3 carbon in the combustible substances.
- other post-treatment systems:

The total frequency of odour assessments of emitted spent air, measured by the olfactometry process with 50% negative evaluations (ADP odour not perceivable) must

produce a dilution factor of 100. A solids emission value of 75 mg/m^3 can be observed in the air emitted from meal, conveyor and storage systems. The air emitted from heating and air purification systems must be removed through a chimney of an appropriate height.

Odour emissions can be generally reduced or prevented by:

- **designing enclosed working and production areas with windows which cannot be opened;**
- **closed process circuits;**
- **fitting of air locks;**
- **preventing any accumulation of materials which could result in the development of odours;**
- **spent air systems with appropriate air treatment, as shown in Table 6.**

***Table 6* - Reduction of odour emission due to spent air treatment**

Type	**System**
Slaughterhouses Meat-product factories (Smoking installations) ADPs	Biofilters, waste gas scrubbing, active carbons Post-combustion, condensation, absorption, adsorption Wet scrubbing (multi-stage),

	heat treatment, biological treatment, earth filters, biological scrubbers

2.3 Noise

Potential sources of noise in slaughterhouses and/or meat-product factories and ADPs are:

***Table 7* - Sources of noise**

Source	Slaughterhouses	Meat-product factories	ADPs
Animal delivery	X		
Animal slaughter area	X	X	X
Machine and process area	X	X	X
Spent air system recooling chamber	X		

As the operations under discussion here are not noise-intensive, technical measures - such as the fitting of sound absorbers etc. - are usually sufficient to comply with local limits/guide values. The possibility of keeping at an adequate distance must be checked first.

It is possible to avoid or reduce noise by:

- **installing sound dampers in ventilation systems;**
- **enclosing machines;**
- **using sound-barrier walls;**
- **making allowance for the main wind direction at the design stage in terms of sources of noise.**

2.4 Waste and residues

There are two types of waste in the meat-processing industry:

- **waste material which can be reused for the manufacture of by-products;**
- **waste to be destroyed or stored in dumps.**

Odour emission in the processing of waste to by-products is reduced by:

- **immediate processing of waste;**
- **cold storage of waste until reprocessing;**
- **use of closed containers;**
- **spent air treatment by appropriate installations.**

If possible, a wet extraction process should be avoided in ADPs in view of the residues this

leaves behind in the end product (animal meal); the pressing process should be used instead.

Waste which goes for further processing, destruction or storage in dumps, should be collected in separate containers (metal, plastic, paper etc.).

Manure should be reprocessed as far as possible for agricultural purposes.

2.5 Waste heat

The operations considered here produce waste heat primarily from:

- boiler house installations;
- cooking and smoking installations;
- open-hearth furnaces (pig slaughter);
- extract cooling (ADP).

State-of-the-art heat recycling plants must be used in new plants, to ensure a lower consumption of primary energy (see also environmental brief Renewable Sources of Energy).

2.6 Industrial safety

The well-being of people employed in the meat-product processing industry is affected in relatively few areas. Noisy machines are used, for example, to saw carcasses into pieces (approx. 90 dB(A)) and to grind meat with cutter mixers (approx. 80-90 dB(A)), and so here appropriate hearing protection is to be worn.

ADP personnel is exposed to odours for a short time when the raw material is delivered, but suitable ventilation and air-extraction systems can reduce this problem, with protective mouth masks recommended in some cases.

2.7 Location planning

Modern slaughterhouse sites are divided by a fence into a clean and an unclean zone, each of which has its own entrances and exits.

The unclean zone houses all activities where cleanliness is not an issue, such as the cattle market, stabling, transport of waste, confiscated carcasses, preliminary clarification, middens etc.

The clean zone is for all areas where hygiene is a major consideration, such as the slaughter plant, cold chambers, cutting plants, dispatch etc.

When designing slaughterhouses, the siting of the clean zone must be analysed and specified appropriately for hygiene reasons in terms of wind direction and emissions from existing or planned works or factories.

3. Notes on the analysis and evaluation of environmental impacts

Limits and approximate values are specified for wastewater and air pollution and are laid down in Germany, for example, in the *Wasserhaushaltsgesetz* [Federal Water Act] and in *TA-Luft* [Technical Instructions on Air Quality Control] or in the guidelines *(Richtlinien)* of the Association of German Engineers VDI; they also describe the correct analysis procedure. Constant wastewater and outgoing air control is necessary to conform to these values, and this also involves checking that technical laboratory conditions are adequate. It must also be ensured that suitable numbers of qualified personnel are available for the analysis work.

The adverse effect of noise on nearby utilities can be reduced by keeping appropriate distances; in Germany, for example, a distance of 350 m from the nearest residential building must be observed. Within the plant, hearing protection must be provided for personnel at noise-intensive workplaces and the wearing thereof checked. Values for the maximum admissible noise nuisance at the workplace are included, in Germany for example, in the *Arbeitssttttenverordnung* [Ordinance on Workplaces].

Waste recycling produces, in the main, odour emissions, but this nuisance can be minimised in the neighbourhood by appropriately designed operating procedures (immediate processing, cold storage, closed containers) and adequate plant distances.

Appropriate dumping facilities must be guaranteed for waste.

The possibility of any residues remaining in the end product must be ruled out by an appropriate choice of process; end products must be controlled by continuous analysis. In new installations, waste heat is returned to the process.

If there are no national provisions, analyses should be carried out to define the preconditions for protecting the population from pollution, e.g. in the form of groundwater pollution, the storage of waste and the associated risk of disease. This applies correspondingly to industrial safety.

Factors of a socio-economic nature must also be analysed, with due consideration given to employment opportunity issues and working conditions, differentiated by sex, and an examination of sources of income for women etc.

4. Interaction with other sectors

Raw material procurement for the meat industry - in this case live animals - and the waste and by-products arising from animal slaughter and the meat-processing industry, give rise to a range of interactions within this sector of industry.

The following special recycling facilities are therefore provided for waste and by-products from slaughterhouses and meat-processing plants, as shown below.

Table 8 - Waste recycling potential

By-products and waste product	Secondary industry	Product	Use
Blood	Blood reprocessing	Plasma	Food industry
Technical blood	ADP	Blood meal	Animal fodder
Hair	Brush processing	Brush/paint brush hair	General
Manure	--	Compost	Fertilizers
Content of intestines	--	Biogas	Energy
Skins, pelts	Tanneries Leather industry	Leather	Leather items
Bones (not fit for human consumption)	Fat production	Technical fats Bone meal	Soap industry Animal fodder
Bones (fit for human	Fat production ADP	Fat gelatine	Food industry

consumption)		Hoof meal	Fodder
Hoofs	Fat production	Technical oils (acid free)	Lubricants
Suet		Edible fat	Food industry

Since slaughterhouses are provided for the general supply of meat and to serve meat-processing factories for the production of meat and sausage goods, and since the by-products and waste constitute the raw material base for these secondary processing plants, there are close links between the businesses in this sector.

The following environmental briefs provide more detailed information about the surveying, evaluation and reduction of environmental impact caused by the meat-processing industry:

Wastewater Disposal
Solid Waste Disposal
Livestock Farming
Veterinary Services
Planning of Locations for Trade and Industry

5. Summary assessment of environmental relevance

The main environmental impact from slaughterhouses and meat-processing plants derives from wastewater, as the pollutant waste load produced in the process is absolutely enormous. If this wastewater (effluent) is discharged into receiving bodies, a fee should be charged, based on the pollutant load.

In addition to the wastewater, serious environmental implications (e.g. odour) can be caused if the critical areas/plants are not maintained as required and waste storage or removal is not carried out with due care.

Unless they are subsidised, slaughterhouses are financed solely by slaughter fees paid by users. The fees are higher the greater the investment and maintenance costs.

The provision of state-of-the-art slaughterhouses can therefore lead to increased meat prices.

In the light of these factors, there is a risk that animals will not be slaughtered in municipal slaughterhouses under veterinary control, but unregulated outside the slaughterhouse (e.g. on the road side) to avoid slaughterhouse fees.

A further crucial point which must be considered when designing such plants, is the availability of technically trained personnel.

Correct plant operation with due allowance made for environmental imperatives can only be

guaranteed if the technical installations are correctly designed and the following conditions are met:

- **availability of adequately trained personnel;**
- **understanding of environmental protection constraints;**
- **implementation of preventive maintenance;**
- **adequate spare part supply.**

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54. Mills handling cereal crops

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1. Scope

The sector embraces mills handling cereal crops, including warehousing for raw materials and end products, and also animal feed production and seed dressing, operations which are almost always linked to the cereal processing complex.

The only milling industries to be considered in the study are those involved in manufacturing end products for human consumption from raw materials imported or grown in rural areas, with animal feed simply a by-product.

Below, the environmentally relevant factors of noise, dust, process water and pesticides are

considered.

The sector concerned can be divided essentially into four parts:

- storage, drying and seed dressing,
- flour mills,
- hulling mills,
- heat treatment.

Projects for the drying and storage of locally grown cereal and for seed conditioning have been given a boost recently and have been priority now that it is realised that raw materials for food need to be protected from spoilage and perishing due to climatic conditions, pests etc. and that better seed increases production.

Modern industrial mills have an integrated silo and warehouse capacity for the raw material to be processed and the end products and by-products manufactured. Depending on the site, ownership and the general purpose of the plants, drying and seed cleaning plants may be incorporated. By-products are often recycled as animal feed components.

2. Environmental impacts and protective measures

Given the processing techniques employed today, it may generally be assumed that large volumes of air are required to produce milled and hulled products (flour, wholemeal products, flakes, grains etc.), in addition to power for cleaning, hulling, grinding (milling) and the transport of intermediate and end products.

This air is used mainly for vertical and horizontal transfer inside the milling or hulling system and for dust extraction from the processing units and the entire mill complex. Furthermore, under certain climatic conditions cool air is required to ventilate power plant and processing machinery as well as the entire building complex.

Industrial wastewater is produced only in the cereal washing department in the mill industry, and even then only where granular or wholemeal products are to be produced. The modern mill industry makes particular use of a dry cleaning process which separates out impurities by means of screens and weighing sorters. If the plant also produces bulgur and parboiled rice, process water with a low starch content is produced.

The wastewater from waste-recycling power generating plants, particularly that from rice husk gasification for the production of lean gas for gas-engine powered plants, has a phenol content of over 0.03 mg/l. When husks are burnt to produce steam, a residual quantity of 18% ash in relation to the quantity input must be disposed of. The same applies to gas plants.

It can therefore generally be stated that the environmental impacts of the mill operation lie in

the following areas:

- dust emission,
- noise nuisance,
- hazard of dust explosions and fires,
- odour nuisance to a limited degree,
- hazard of toxic gas,
- recycling of residual substances and waste disposal,
- process water.

2.1 Cereal storage and handling

2.1.1 Port and transshipment silos, mill silos

Storage installations of this kind are used for the storage and transshipment of cereal for import and export. They are found in all major ports where imported cereals (wheat, maize, rice, millet etc.) as well as raw products and semi-finished products for the food and animal feed industry are put into store for intermediate storage, and from which the domestic industry is supplied with raw materials or goods for export are shipped (maize, rice, millet, tapioca etc.).

The following table shows the dust content of the service air from the various mill sections and admissible emission values in Germany.

***Table 1* - Pollutants produced and admissible emission values in Germany**

Type of mill industry	**Dust content of service air**		**Permissible emission values**
Silo installations	12 to 15	g/m3	50 mg/m3
Drying plants	15 to 18	g/m3	50 mg/m3
Mills handling cereal crops	approx.96	g/m3	50 mg/m3
Hulling mills	6 to 8	g/m3	50 mg/m3
Seed cleaning	8 to 10	g/m3	50 mg/m3

In storage installations with preliminary cleaning plants and in mills, dust emissions are collected in aspiration pipe systems during cleaning, and separated with the help of cyclones and filters. To achieve the best possible removal of dust from machines and buildings, all equipment handling materials and machinery should be enclosed and fitted with appropriate aspiration connections. The extraction of dust with so-called mass separators or filter separators is described and explained in the guidelines nos. 3676 and 3677 of the Association of German Engineers VDI. The safety measures in these guidelines should be observed.

With the high degree of mechanisation in modern mills, the only workplaces where dust is a

problem are the loading and packing operations; here too, extraction devices must be used wherever possible.

All the dust from aspiration systems and cleaning in transshipment silo installations is collected and bagged.

The cleaning waste, which may contain live pests, is to be destroyed immediately.

In mill-cleaning plants, dust waste and granular cleaning waste is treated and added to mill afterproducts (bran) (feed ingredient).

Noise is another environmental problem. The increasing use of high-speed technical equipment and the intensive use of machines in the smallest possible space give rise to an increasing noise nuisance which is becoming a hazard to man.

Precautions must be taken to protect employees and local residents. Structural measures, such as the lining of ceilings and walls with soundproofing materials, must be taken, and vibration isolation materials must be used for machine foundations.

The TA-Lrm [Technical Instructions on Noise Abatement] in Germany lays down, for the various industrial and residential areas and mixed use areas, safety guidelines for immissions which must be observed in the planning and erection of industrial plants.

Personnel must be issued with hearing protection where they are constantly exposed to noise levels of over 70 dB.

Information and training must therefore be provided for personnel, and compliance with safety measures monitored.

People, buildings and the machine stock can be at risk from dust explosions and fires. Following any such explosion, there is a chemical conversion of a dust/air mixture, which accelerates as heat is generated, causing a sudden pressure effect from existing or newly formed gases. Three components constitute the basis for a dust explosion: dust, air (oxygen) and ignition energy; the latter can be in the form of heat or electricity (electrostatic charging).

Silo installations are particularly at risk from dust explosions. Mechanical sparks, pockets of glowing materials, mechanical heating, hot surfaces, welding work, electrostatic discharge sparks and the like are possible ignition sources. They must be eliminated as a safety measure, and the formation of explosive dust concentrations must be prevented, for example by enclosing machines. Structural precautions can also be taken, namely the creation of compression-proof rooms and pressure release and explosion suppressing systems. The following organisational precautions are also effective in terms of fire and explosion safety:

- **welding and cutting works only to be carried out during factory shutdowns;**
- **regular cleaning with dust-explosion-proof equipment;**

- training of employees in the handling of fire-fighting equipment and
- information to employees about the causes of dust fires and explosions.

Finally, in the planning phase, provision must be made for taking all the measures required to limit the risk of explosion (cf. in Germany, VDI guideline, 2263 on dust fires and dust explosions - *Staubbrnde und Staubexplosionen*).

Gases are most commonly used to protect stocks (pest control) in the silo installations and warehouses, but under certain circumstances sprays and vapours are an option.

The types of pest control agent for cereals currently used and approved in Germany include gaseous insecticides:

- hydrogen phosphide,
- methyl bromide,
- hydrogen cyanide.

In addition to gases, fumigants and sprays can be used for the disinfestation of silos and stores - without any need to include stocks in the treatment.

The following are approved in Germany:

- lindane

- **bromophos,**
- **malathion,**
- **dichlorvos,**
- **piperonyl butoxide,**
- **pyrethrum**
- **and combinations of these.**

The incorrect use of agents for pest control for stock protection purposes can lead to hazardous substances seeping into adjacent production or residential buildings (e.g. hydrogen phosphide). Therefore, particular attention must be paid to the technique of pest control (e.g. silo fumigation using a circulation system).

Specific bans or restrictions on the use of these agents are recorded in the plant pesticide register of the country concerned or may be requested from the registration office for these substances. The manufacturer's instructions must be strictly observed and made available in the local language.

After treatment, waiting periods must be observed to ensure that plant products do not contain higher residue levels than are permissible where they are to be brought into circulation or eaten (cf. environmental brief, Analysis, Diagnosis, Testing and Volume III, Compendium of Environmental Standards (CES)).

Authorised contractors must be employed for the application of agents to protect

commodities stored in silos and warehouses; their personnel must be appropriately trained and able to use the special equipment and safety installations.

2.1.2 Cooperative stores and warehouses

Simple storage installations (including raw material stores) are warehouses for bagged commodities or for horizontal storage. Bagged commodities or loose grains are cleaned, stored, ventilated and may also be treated as a pest control measure. Most maize, rice and sorghum harvests are still stored in this way in many countries, with possible storage losses of 15% or more.

***Figure 1* - Diagram of a port and transshipment silo installation**

Standard warehouses should also have installations for cleaning, ventilation and fumigation.

The risk of dust explosions can be largely avoided in warehouses by a light and open design, although this does not protect against normal types of fires which can occur. Otherwise, the environmental implications are as described in 2.1.1. Pest control in warehouses may take the form of sprays although fumigation is also commonplace.

The safety measures for silo installations described in 2.1.1 are also applicable to warehouses, with the exception of measures against the risk of explosion.

Special precautions must be taken where gases are used for pest control purposes. As bagged commodities cannot be fumigated in airtight areas, gastight fumigation tarpaulins, sealed underneath with sand, are required if this type of pest control is to be used.

2.1.3 Seed cleaning installations

Seed dressing is not considered part of a mill's activities, but in many countries it is one of the services a cooperative storage facility may offer its members.

In using these facilities seed is produced with a higher grade purity thanks to air, screen and specific weight classification. The lower content of other types of grain and the improved growth conditions resulting from chemical treatment improve quality and thus yields per hectare.

The service air from seed cleaning plants contains primary dust. It and the cleaning waste produced (rejected grain, weed seeds etc.) can be used for animal feed production.

Treatment involves the wet or dry application of fungicides and insecticides which - as pesticides - protect the seed and are classified as seed treatment agents. All such treatments approved by the Biologische Bundesanstalt fr Land- und Forstwirtschaft (Federal Biological Research Centre for Agriculture and Forestry) in Germany are listed in the pesticide register *Pflanzenschutzmittel-Verzeichnis* (1990).

These plant pesticides are used in seed improvement operations either alone or in combination depending on the purpose of the treatment.

Common pesticides (active ingredients) are:

- **anthraquinone,**
- **bibertanol,**
- **bendiocarb,**
- **fuderidazol,**
- **bromophos,**
- **lindane,**
- **carboxin,**
- **fenfuram etc.**

Environmental measures in seed cleaning operations are confined, in terms of aspiration and service air, to keeping the production rooms and the outgoing waste air clean. The filter installations listed in paragraph 2.1.1 and the emission values shown in table 1 are applicable here.

When protecting seeds, appropriate precautions must be taken to protect personnel and, subsequently, users.

The approval regulations of the individual countries must be obeyed as must the

manufacturer's recommendations for use (see too Volume III, CES).

Figure 2 **- Diagram of a seed cleaning installation**

2.1.4 Drying installations

Grain drying is a thermal process in which water is removed from the pre-cleaned damp commodities (cereal, maize, rough rice (paddy), sorghum etc.) by evaporation. Obviously, an adequate supply of heat is essential. The drying of the moist harvested produce is usual in warehousing facilities and the agricultural trade (cooperatives), and mill and silo facilities often have drying installations too. Thus, wherever large quantities of damp grain (moisture content of over 15%) are supplied, rapid drying is called for. Drying installations are used where natural sun drying is not practicable in view of the weather conditions (rainy season). Only dry commodities can be safely stored for prolonged periods without any deterioration in quality.

The service air of drying installations and the preliminary cleaning machines contains coarse to fine particles of dust which need to be separated by means of the dust separators described in paragraph 2.1.1. Drying installations are only used at harvest time, and should preferably be sited close to the (sparsely populated) growing areas. Noise is another problem. Very often mill and silo facilities also have drying installations.

The safety measures listed in 2.1.1 to protect against dust and noise must be taken here too.

Figure 3 - Diagram of a drying installation

2.2 Flour mills (wheat mills)

The purpose of a flour mill is to obtain large quantities of flour which also meet flour product requirements in terms of quality. The by-products and afterproducts (bran, middling and cleaning waste) are recycled in agriculture or in the animal feed industry in the form of feed components. Mills also make wholemeal products.

In some cases, very antiquated washing machines are still used today for cereal cleaning in the wheat mill industry, requiring monitoring of wastewater quantities (up to 1000 l/t), thus safe distances from residential areas must be maintained. In the modern cereal mill, water is only used for conditioning (wetting) the cereal and it is fully absorbed by the grain. Today, the entire cleaning process is carried out by means of air, screening and weight classification. Scouring machines have largely replaced the washing systems, thus no industrial wastewater is now produced.

In conventional mills handling cereal crops, some 5 - 10 cubic metres of air are required per milled tonne. This quantity drops to just 15% where machines working on the circulating air principle are used for cleaning. All service air discharged into the atmosphere must be filtered.

There is also a fire risk due to dust explosions in mills, and mills handling cereal crops as a

whole generate noise emissions which have environmental implications for humans.

All safety measures described for cereal storage are appropriate for mills handling cereal crops in all respects. If silo installations are structurally linked to the mill, not only must automatic fire valves be fitted in the interconnecting materials handling equipment, but also the connecting walls between the installations must constitute fire barriers21). A settling tank for organic substances (husks, pieces of stem, fines etc.) must be provided.

21) For this reason, safe distances from populated areas must be maintained.

Figure 4 - Diagram of a wheat mill

2.3 Hulling mills

Hulling mills handle the following cereal types: oats, barley, rice, sorghum and millet, as well as pulses. While hulling mill technology is very different from that used in mills handling cereal crops, the environmental pollution and the resultant safety measures are largely similar in both types of mill.

2.3.1 Rice mills

The process from rough rice (paddy) through to ready-to-use white rice passes from cleaning with air, screening and weighing, dehulling and the polishing process (removal of the

aleurone layer) through to sizing. Some countries have their own production from low to medium capacity rice mill facilities (China, Taiwan, Malaysia, Thailand, India and some South American countries).

The environmental pollution from rice mills in these countries is considerable if there are no complete aspiration systems or such systems are not designed to appropriate technical standards. Often, cyclones alone are used for dust separation although they only achieve a separation level of 90 - 95%, with dust emissions standing at 70 to 150 mg/m^3 air. Dust filters must be used.

The major disposal problem for rice mills is presented by the rice husks from the production process (20%). One possible means of economically recycling rice husks is that of pyrolysis to produce energy in steam power plants or lean gas for gas-engine plants (see environmental brief Plant Production).

Hot industrial water (approx. 65C) and saturated steam are used to make parboiled rice (rice precooked in the husk).

Apart from the rice husks, all other by-products are either used locally as animal feed or exported (rice polish/emery flour).

A residue of about 18% ash is produced by rice hull pyrolysis. Ash can be disposed off locally as a soil structure improver and more recently rice hull ash has been used in steel works as

an insulant.

Where parboiled rice is produced, organic substances are found in the wastewater, but in such small quantities that their recovery is not economical. Approx. 1 cubic metre of drinking quality water is required per tonne of rough rice (paddy), approximately 30% of which is absorbed by the grain.

Otherwise, the environmental impacts are as described in paragraphs 2.1.1 and 2.2.

The environmental protection measures to be observed for rice mills are listed here in order of priority:

- **Dust emission values as applicable in mills handling cereal crops must also be observed in rice mills, i.e. modern aspiration systems with separators and filter installations must be used.**
- **Noise emissions are a nuisance to the population living in the surrounding area and so the details per sections 2.1.1 and 2.2 apply for this industry.**
- **The use of biodegradation tanks is recommended for wastewater disposal from parboiling facilities because of the higher starch concentrations.**
- **Measures must be taken to ensure proper hull disposal. In addition to pyrolysis and soil structure improvement, the hulls can be used in the brick industry, distilleries and possibly for furfurol production. Other uses are technically feasible and should be considered in the light of the particular site.**

2.3.2 Hulling and processing of sorghum and millet

The industrial processing of sorghum and millet produces flours with good keeping properties and enables quality to be controlled in the light of the end products to be made. Better quality flours and higher yields are therefore achieved.

The upturn in the fortunes of this new branch of milling has been further enhanced by the possibility of blending this flour with wheat flour (composite flour). This has enabled a number of countries to use local raw materials by producing flours of this kind (blends of up to 20%).

The pollutants produced and safety measures to be taken are based on the data in paragraph 2.2.1.

2.3.3 Pulse hulling

The produce processed in hulling mills includes a range of pulses which are grown in temperate climates as well as the tropics. Pulses such as chickpeas, lentils and local bean varieties are brought onto the market in their hulled/split form or as flour.

The pollutants produced and safety measures to be taken are similar to the substances and measures described in paragraph 2.1.1.

2.4 Location planning

When planning the location of a food industry facility, it must be assumed that medium-sized and large operations will be accommodated. In such mass-production plants where food is processed, manufactured, transported, loaded and unloaded or stored, the following environmental factors must be taken into account, for which detailed information can be found in the relevant environmental briefs:

- **An organised transport system is necessary as facilities of this kind turn over substantial quantities of raw materials and finished products (environmental brief and Transport and Traffic Planning).**
- **When planning larger facilities, a sea/land/sea transshipment facility should also be provided (environmental briefs Inland Ports and Ports and Harbours, Harbour Works and Operations).**
- **As facilities of this kind run day and night, they must be sited at appropriate distances from residential areas. Dust, and above all noise nuisance, must be prevented (environmental brief Planning of Locations for Trade and Industry).**
- **There should be a reliable energy supply on site to ensure safe operation of larger plants (environmental brief Overall Energy Planning).**
- **Furthermore, for safety reasons, they must be sited further from other industrial plants so that in the event of incidents (fire, dust explosion) extensive damage can be avoided.**

- A water supply and organised disposal facilities are absolutely essential (environmental brief Water Framework Planning, Wastewater Disposal).

The fundamental factors in site selection (e.g. avoidance of agricultural areas or rare/valuable areas of countryside) are likewise to be found in the environmental brief on Planning of Locations for Trade and Industry.

2.5 Energy from husk waste

The energy requirement of milling plants ranges from 30 to 70 kWh per tonne of end product, and that of rice mills 30 kWh. One economic and environmental objective should be the use of the husks from rice production (approx. 20%) as a source of energy.

Waste gas emissions from the chimneys of steam power plants are becoming an environmental problem due to their ash particle content. When incinerated, a residual quantity of about 18% ash remains.

Where gas is produced from husks, industrial water is used for gas scrubbing to separate tar and dust, and also as cooling water for the gas reactor. This wastewater contains up to 1.6 mg/l phenol. The ash produced by husk pyrolysis must also be disposed of.

All residues from husk burning in the ash disposal section of steam power plants should be collected in its dry form; after cooling and intermediate storage, the ash can be reused by

agriculture and industry. Fly ash in the chimney must be separated by scrubbing with dust separators before it enters the waste gas chimney.

Wastewater from gas generators may only be released once it has been neutralised and freed from solids. Venturi scrubbers and biological plant tanks must be used for tar separation.

Even at the planning stage of these power plants, ash disposal, flue gas emission and wastewater disposal must be considered in the light of parallel municipal development.

2.6 Further processing of cleaning waste and mill afterproducts

Normally waste from mills handling cereal crops is immediately milled in hammer mills and then, together with mill afterproducts, supplied to the animal feed industry. Other mill afterproducts are bran and low-grade flour, and from the hulling mill, hull bran.

This industry, often regarded as a secondary operation in mills, produces fodder concentrate for livestock farming, which contains protein, carbohydrate, fats, mineral substances and vitamins as its main blending components.

2.7 Dust disposal

Dust requiring disposal is produced only in the goods inward sections of agricultural trade

establishments and cooperatives. This dust actually consists of sandy impurities which are separated when the commodities enter the preliminary cleaning plant, and can, for example, be returned to the supplier.

3. Notes on the analysis and evaluation of environmental impacts

Large quantities of service air are used for transport, separating processes, heat discharge and aspiration in flour and hulling mills where the process technologies comprise milling and sifting techniques and abrasive and centrifugal hulling. This dust-laden air must be treated, making dust removal from air a priority concern.

Furthermore, the noise produced in such installations must of course also be given due consideration.

When planning mill projects, the various national limits must be taken into account at the design stage; if there are no adequate legal provisions, international standards must be applied. The provisions and limits applicable in Germany are quoted below by way of example.

The following legal standards and technical regulations are valid in the Federal Republic of Germany for the area under consideration:

Bundes-Immissionsschutzgesetz, Neuauflage (New Edition) 1990

TA-Luft, 1986
TA-Lrm, 1986

VDI-Handbuch Reinhaltung der Luft, Band 6;

VDI 2264, VDI 2263
VDI 3673

Arbeitsbltter der Abwassertechnischen Vereinigung (ATV), November 1980 Issue

Biologische Bundesanstalt fr Land- und Forstwirtschaft

Pflanzenschutzmittel-Verzeichnis 1990.

Almost all afterproducts from flour and hulling mills can be recycled in the animal feed industry, are potential sources of energy or can be used as raw products or auxiliary materials in subsequent processing industries (oil mills and breweries, steel industry and foundries).

Emission values for local environmental protection in Germany are those specified in the TA-Lrm (Technical Instructions on Noise Abatement). The guideline of the German Association of

Engineers no. 2058 requires noise protection at the workplace, with the issue of personal hearing protection from 85 dB(A) upwards, and the wearing of this protective gear from 90 dB(A). These workplaces should be labelled and compliance with safety measures monitored.

Noise level and air quality measurements in the flour milling industry provide information about environmental impact and the safety measures required to be taken.

Table 2 - **Noise levels in mills handling cereal crops**

Machine/part of building	**Noise level dBA**	**Frequencies Hz**
Separator floor	105	1000 to 2000
Sifter floor	100	800 to 1200
Roller floor	105	1500 to 1800
Hulling machines	108	1800
Compressors	95	2000
High-pressure ventilators	100	2500

This data shows that not only external noise emissions, but also workplace conditions inside the plant need to be dealt with by effective safety measures22).

22) such as machine enclosures and the wearing of hearing protection.

The Compendium of Environmental Standards provides information on assessment with regard to individual substances.

Where combustible substances are used for drying, only those with a maximum sulphur content of 1.0% are permissible.

4. Interaction with other sectors

Mills handling cereal crops perform numerous additional activities upstream and downstream, for example plant production, transport, and the handling and use of products obtained, e.g. as food. There are therefore a number of connections with other sectors; these are indicated in the text by reference to the relevant environmental briefs.

5. Summary assessment of environmental relevance

Afterproducts resulting from the process or raw materials used, which are in almost all cases used as fodder concentrate components, are produced in flour and hulling mills and in the

associated drying and seed cleaning plants which process cereal and tropical grains into food for human consumption. In contrast, rice mills give rise to environmental pollution from the recycling of the husks (steam production).

Dust, which is an ever-present combustible, is a health hazard, potential source of ignition and a danger in the storage and milling industry. Precautions are taken in the form of constant maintenance and monitoring of extractor plants, dust accumulation, with temperature and humidity adjustment as associated preventive measures; personnel must be suitably be trained for this.

The emission guide values applicable for local environmental protection with regard to noise, insofar as they concern the area of production, are binding on the industry and must be observed by measures such as providing safe distances or soundproofing. Inside stores and mill buildings, the noise level is a serious problem for the employees. In the light of all we know about the long-term effects on hearing, due account must be taken of noise protection requirements at the workplace. Personal hearing protection must be issued and its use monitored.

The use of insecticides and pesticides for pest control purposes and seed disinfestation also presents problems since the substances used are highly toxic and health problems can be caused through their uncontrolled use and circulation. Only specially trained personnel using the correct equipment should be employed in these operations.

A certain amount of experience has been acquired in the field of the degradation of organic substances in process water with the help of fermenters, but a degradation tank is recommended where the wastewater is heavily polluted.

Modern mills do not give rise to substantial emissions and residues which pollute wastewater and dumps. Industrial water is only used for conditioning purposes in mills handling cereal crops and is absorbed by the grain. Mill installations with washing plants have to meet minimum requirements for the disposal of organically loaded wastewater. The same applies to industrial wastewater from bulgur or parboiled rice production.

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VDI-3677, Filternde Abscheider

VDI-3679, Naarbeitende Abscheider

VDI-2263, Staubbrnde, Staubexplosionen

VDI-3673, Druckentlastung von Staubexplosionen

VDI-2057, Einwirkungen von mechanischen Schwingungen auf den Menschen

VDI-2711, Schallschutz durch Kapselung.

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55. Vegetable oils and fats

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1. Scope

This environmental brief discusses the extraction and processing of oils and fats from vegetable sources.

Vegetable oils and fats are used principally for human consumption, but are also used in animal feed, for medicinal purposes and for certain technical applications. They are extracted from a range of different fruits, seeds and nuts. Unlike industrial oils and fats, which are mostly produced from petroleum, they are generally non-toxic and biodegradable, without requiring any further treatment. However, they pollute the environment as they degrade due to their oxygen demand and their capacity to break down into water emulsions. An overview of the main types used is shown in Table 1(23).

(23) Table 1 shows only the most common types. In many countries, a range of other varieties is used in part on a small industrial scale, e.g. rice bran, cashew nut, safflower, mahua, neem, mustard, tobacco, rubber plant, khakhan, dhupa, kokum, thumba seed and others besides.

***Table 1 -* Use of various fruits, seeds and nuts**

Use*)	**Seeds**	**Nuts**	**Fruit and fruit flesh**
For human consumption or medicinal purposes and	Cotton seed Sunflower seed Soya beans Palm kernels	Coconut Hazelnut Walnut Peanut	Palm fruit Olives

animal feed	Cocoa beans Sesame seed Corn (germ) Rapeseed Linseed		
For technical applications and fuel	Castor oil plant Linseed Perilla seed Oiticica seed	---	---

***) The subdivision into use for human consumption and use for medicinal and technical applications is based on the principle application and may change. For example, rapeseed, palm kernels, soya beans, sunflower seeds and peanuts are potential raw materials for fuel production (Elsbett motor).**

Production processes for vegetable oils and fats differ according to the required yield and raw material type. They can be categorised as follows:

- **fruit processing**
- **processing of seeds and nuts by mechanical extraction (pressing)**
- **processing of seeds and nuts by solvent extraction.**

Processing, in which the raw materials are separated into oils and oil-bearing solid residues, comprises the following operations after harvesting and any storage:

1. Preparation by raw material husking and cleaning, crushing and conditioning[24]**.**

[24] **Conditioning means treating the raw material so that it has certain chemical or physical and chemical conditions in order to obtain the highest possible oil yield from the subsequent pressing operation.**

2. a) Boiling of the fruit or
b) Pressing or pressing and/or
c) Solvent extraction of oil-seeds/nuts.

3. a) Skimming of the liquid oil phase if boiling is carried out
b) Filtration of the pressed fat if pressing is applied
c) Separation of the crude oil while at the same time evaporating and recovering the solvent where solvent extraction is carried out.

4. Conditioning (drying) and reprocessing of residues.

5. Crude oil improvement by refining

a) Degumming

b) Neutralisation
c) Bleaching
d) Deodorisation.

6. Further processing of the refined crude oil.

2. Environmental impacts and protective measures

The intensification of land use in connection with projects for oil and fat production can have negative environmental implications (single-crop agriculture, erosion, water and soil contamination, loss of soil fertility, destruction of wildlife habitats). Farming methods and harvesting practices must be controlled and optimised from the outset.

2.1 Hazard potential of the different processing stages

The forms of environmental pollution shown in Table 2 below can arise during intermediate storage and the different stages of processing.

***Table 2* - Hazard potential during storage and processing**

Type of	Storage	Cleaning	Pressing	Extraction	Refining	Packing

pollution		Crushing Conditioning	Boiling		Improvement	
Dust		X		X		X
Noise		X		X	X	
Pollutants (including smell)	X	X	X	X	X	X
Wastewater	X		X	X	X	X
Flue gas			X*)			
Waste/special waste		X	X	X	X	

***) From the burning of palm fruit stems, which have a residual oil content of 0.38%, in charcoal kilns.**

2.2 Processing of fruits (palm fruit, olives)

Fruits are processed in the producer countries in the tropics (palm fruit) or around the Mediterranean (olives) by relatively small rural concerns and by medium-sized industrial companies. Figure 1 gives an overview of the various production processes, and in the following we examine in detail palm fruit processing.

***Fig. 1* - Oil production from fruits**

With palm fruit, some 2 to 3 tonnes of wastewater are produced per tonne of crude oil. Due to its organic residues, the wastewater has a particularly high biological and chemical oxygen demand for cleaning (water pollution). Moreover, dissolved solids (sludge particles), oil and fat residues, organic nitrogen and ash residues are the principle constituents of the wastewater.

The first operation in the treatment and reprocessing of wastewater is that of separating settleable solids. The residual oil content is collected in an oil trap. There are also combined sludge and oil traps which are oil traps with an integrated sludge chamber and are 92% effective. A 100% reduction in wastewater and pollutant discharge into surface water can be achieved by any of the following measures:

discharge by spraying
discharge by other irrigation systems
drainage into settling tanks
drainage into municipal and urban sewage treatment systems.

No soil conservation problems due to wastewater penetration have been reported to date.

Additional storage facilities and areas should be kept in reserve in case of leaks of solvents, lyes and acids in the event of accidents, and equipment to deal with such accidents should

be to hand at all times.

Figure 2 shows a percentage analysis, based on 100% palm fruit bunches, which can be used to estimate the potential waste and wastewater volume.

Fig. 2 - Palm fruit processing with percentage analysis

Minimum requirements for wastewater drainage into watercourses in Germany are laid down by the 4. Abwasser-Verwaltungsverordnung (4.AbwVwV) [4th Wastewater Administrative Regulation] of February 1987, some details of which are shown in extract form in Table 3 below as a guide.

Table 3 - Minimum requirements (from 4.AbwVwV)

	Quantity of wastewater in m3/t initial product	Settleable solids ml/l	Chemical oxygen demand (COD) mg/l			Extractable substances mg/l
		Random sample	Mixed sample*)			Mixed sample*)
			2 h	24 h	2 h	24 h
Seed dressing	10	0.3	200	170	30	20

Edible fat and oil refining	10	0.3	250	230	50	40
	10-25	0.3	200	170	30	20

***) Within 2 to 24 hours**

An alternative, more environmentally friendly method than draining wastewater into surface water consists of recycling the wastewater as process and boiler feed water (circuit system). The World Bank "Environmental Guidelines" (see item 6 in References) gives a technical description of biological wastewater treatment methods for palm oil extraction plants as practised in Malaysia.

Considerable quantities (per tonne of raw material, approx. 0.7 to 0.8 tonnes) of waste of vegetable origin (cellulose, husks, stems, pressing residues) arise during production, and the disposal of them must be taken into account when such facilities are planned. Due to their content of oil-bearing, organic components, the stripped bunches pose a major odour problem, as do pressing or extraction residues. Transport and dumping should be organised on this basis (e.g. dumping far from populated areas). The remaining solid residues are often incinerated to produce process steam, although this is not an ideal form of recycling as the waste contains silicates which vaporise when burnt and form a glassy coating in the furnace. It should be ensured that the incineration process is controlled and waste air is not used to separate the husks from the kernels (contamination with silicates) as is frequently observed. Heat exchangers with integrated self-cleaning systems are one possible solution. The

incorporation of organic waste (mulch) in farmed arable soils raises a number of problems as the soil cover could, under certain circumstances, be destroyed (erosion risk) if waste were ploughed into it. On the other hand, prior mechanical comminution of the waste - which would facilitate its application to arable soils - could nullify its cost effectiveness, although under certain circumstances it would make a practical contribution to soil structure improvement.

2.3 Processing of oil-seeds and nuts

Three different processes may be used to extract the oil from oil-seeds and nuts:

- **pressing**
- **solvent extraction**
- **a combination of pressing and solvent extraction.**

Processing produces waste, dust and odorous substances as well as wastewater in a quantity of some 10 m^3/tonne seed. Cylinder mills, fans and pneumatic conveyors are also sources of noise.

Figure 3 provides an overview of the processes used.

The environmental implications arising and the environmental protection measures which can be taken are described below in the sequence of the individual processing stages.

Fig. 3 - Oil production from oil-seeds and nuts

2.3.1 Storage

There are three methods of storage:

- bagged under cover
- loose in a warehouse
- loose in a silo.

Dust is produced during the filling operation in the latter two cases, in variable quantities depending on the equipment used. The dust is of organic origin and relatively harmless (direct contact is unpleasant and can cause skin irritation, visual and respiratory difficulties). If only because of dust explosion risk, aspiration (extraction) is essential for the mechanical processes described below (cleaning, crushing, conditioning). Thus instead of quantities of dust being released during the cleaning, screening or crushing operations, the dust-laden air is extracted, collected and cleared of solids via a central dust-removal installation, normally cyclones (maximum separation efficiency of 95%) or, better still, via filters (separation efficiency of up to 99%).

If mould should be found and if the presence of aflatoxins is suspected (in peanuts), there is no risk of contamination of the soil or groundwater under the stores, as the metabolism of the particular mould fungi limits the presence of aflatoxins to the food product only (peanut kernels). Preventive measures (air humidity control and monitoring) and the regular checking and sorting of stocks are essential here. Any possibility of the fungal spore dissemination must be eliminated (prevention of strong air currents, stores to be protected from the wind), otherwise peanuts not yet affected can be infested, causing health risks to employees as the spores can enter the lungs and, once established there, can multiply.

2.3.2 Cleaning and crushing

The mechanical cleaning and crushing of oil-seeds and nuts generate noise and dust, which can be controlled by aspiration and dust-extractor installations (collecting filters, electrostatic precipitators/cyclones) - thereby also preventing dust explosions.

2.3.3 Raw material conditioning

Raw materials are generally conditioned by the addition of steam (heating), an operation which enables the degree of wetting of the product to be controlled. The so-called vapours, the odorous substances, are released as condensate. Gaseous emissions and emissions of odorous substances can be limited by cleaning the

outside of machines and pipes with alkalis (caustic soda, caustic potash). The sulphur content can be determined by the analysis of the local raw material to be processed, and on the basis of this appropriate emission monitoring equipment can be developed.

2.3.4 Pressing process

No environmentally relevant substances other than the vapours are produced in the preliminary and final pressing of oil-seeds. However, during the washing (usually with steam jets) of the fat-sprayed machines, oily water is drained into the wastewater system. Here too oil traps are required. The heat from the vapours can be recovered in heat exchangers as an energy-saving measure and to reduce odours.

2.3.5 Solvent extraction

In the fluid extraction process, the oil in the unpressed or prepressed products is chemically dissolved with solvents and discharged in the form of miscella (oil-solvent mixture) (see figure 4).

The solvent most commonly used is hexane (C_6H_{14})25) which is to be regarded as both a nerve and an environmental poison. Hexane-contaminated production residues must therefore be treated or disposed of. The following can be contaminated with hexane: the air, extracted product, miscella (residual oil-solvent mixture) and water.

25) Hexane is a hydrocarbon of the paraffin group. It constitutes a fire hazard and must be regarded as a nerve poison. At high concentrations, hexane is narcotic and states of intoxication may be observed, although these are overcome quickly and without any

consequences for health where oxygen or fresh air is provided. In the case of prolonged exposure, paralysis together with cardiac and respiratory problems arise. Severe poisoning can result in death, in some cases weeks later. Constant exposure causes death by suffocation. Some cases of skin irritations through to necroses (tissue destruction) have been observed as a result of hexane and employees must therefore be given training in the handling of hexane. Surplus quantities, which cannot be released into the environment under the terms of discharge regulations (e.g. 4. AbwVwV in Germany) must be disposed of as special waste. In storage, the general regulations applicable to the handling of chemical products should be observed. Hexane can be stored in drums under stands fitted with extractor systems and collector sumps. Another solvent which is sometimes used is benzol, but it is not recommended in view of its high level of toxicity and other problems.

2.3.5.1 Air polluted with hexane

is formed due to leaks in the plant and the conveying pipes.

Hazards: Air-hexane mixture is explosive once the explosion threshold of 1 to 7% is reached.

Remedy: The concentration is measured with probes at suitable points (conductivity meters) and an alarm triggered if the threshold is exceeded. Particular care must be exercised when entering tanks and in all cases fumes must first be removed.

is formed during the extraction process in the extractor and during the subsequent steam

treatment of the extracted product in the toaster.

The waste air can be treated by absorption plants, in which the air is fed through a mineral oil bath and the hexane transfers from the air into the mineral oil. The hexane pollution in the waste air released into the atmosphere should not exceed 150 mg hexane per m^3 air at a mass flow of 3 kg/h. The explosion safety threshold is 42 g/m^3 air.

2.3.5.2 Extracted product polluted with hexane and residual hexane-oil mixture (miscella)

The solid raw material residues and the miscella are largely stripped of hexane by steam distillation, in which meal (animal feed) and a water-hexane mixture are produced, or where hexane and crude oil are separated out from the miscella. The hexane can be collected and reused (hexane recycling).

The hexane content of the meal must not exceed 0.03% for transport safety reasons. As hexane is heavier than air, there is a risk with lengthy transport times that the hexane could sink and concentrate, thereby exceeding the explosion safety threshold (42 g/m^3). As hexane vaporises relatively quickly, no consequences have yet been observed with regard to the health of cattle fed on the meal.

2.3.5.3 Hexane-water mixture

If hexane-contaminated wastewater is to be disposed of, 50 parts per million (ppm) hexane, for a total wastewater quantity of 3 - 5 m^3/t feedstock, should not be exceeded.

Hexane-water mixtures are separated by the density difference and the (theoretical) insolubility of the two media in each other, in order to condition (produce) disposable wastewater. They are separated by the drawing off of the two fractions in a settling tank at 40C. Water, as the heavier fraction, is drawn off at the bottom, while the lighter hexane, which floats, is pumped off from the top. Cooling to 40C is essential so that the separation operation is carried out well below the boiling point of hexane (68C). The residual hexane content in the water is reduced by evaporation in a boiler (90C, to stay below the boiling point of water).

2.3.5.4 Wastewater polluted with hexane

The total quantity of water supplied in the form of steam which is added is 12%, related to the quantity of raw material used in the steam treatments (see 2.3.3). 50% of this remains in the meal, the other half being converted into the liquid state by condensation. Thus some 0.06 m^3 wastewater per tonne of feedstock is contaminated with hexane. It is not possible to give more precise details about potential risks to the environment arising in tropical areas due to non-compliance with this limit (long-term consequences of possible damage to the ecotope) as research in this area is woefully inadequate.

2.3.6 Refining

The oils produced by extraction must - for reasons of durability, taste, appearance and consistency - be cleared of impurities such as free fatty acids, particles of dirt and seed, lecithin, carbohydrates, fats, gummy or mucilaginous substances, pigments, waxes and oxidation products. The purpose of refining is to remove undesirable by-products whilst retaining desirable ones, e.g. vitamins, antioxidants (tocopherols) or certain technical properties. Refining comprises basically the degumming, neutralisation, bleaching and deodorisation of the crude oil, and it is in these processes that most of the wastewater and unpleasant odours are produced. The lyes and acids used in the process bring with them a potential risk of injury to personnel (safety measures and training necessary). Figure 4 illustrates the refining process schematically.

Either a chemical or physical method can be used for oil neutralisation (removal of free fatty acids). The chemical process involves the neutralisation of acid using caustic soda, whilst the physical process neutralises by steam distillation. Physical neutralisation is the norm for palm, coconut and palm nut oil, whereas cottonseed and sunflower oil are generally also neutralised chemically as steam distillation is inadequate in view of the high lecithin content.

Since the treatment of the wastewaters formed is easier, and the quantity of wastewater lower during the physical process, efforts are being made the world over to develop processes which separate off the lecithin in the said oils so that they can be neutralised

physically.

Fig. 4 - Schematic representation of refining

2.3.6.1 Physical refining

During the physical process, the preliminary stage involves degumming the oil, normally with phosphoric acid, which coagulates and precipitates proteins which are then removed in separators. The separated solid matter is added to the meal, from which animal feed is made. To prevent phosphate discharge into the refinery wastewater, phosphoric acid is now being replaced by citric acid, which does not degrade into pollutants because of its organic origin, among other things.

The degummed crude oil is then bleached with active clay (clay with a high silicate content)26), since the natural pigments of the crude oil are adsorbed into the active clay and absorbed into the active clay bed. One of two possible processes is used to recover the residual oil which the spent active clay contains. In smaller plants, a steam treatment is used to recover at least some of the oil, but wastewater is also produced. In large-scale plants, all the oil is removed from the active clay in special extraction installations. The oil recovered in this way is of an inferior quality. The process itself produces wastewater and waste air which contain solvent residues, and must be clarified or purified (separators, filter installations).

26) In some countries, charcoal is used for bleaching, but should be avoided in view of the shortage of resources.

Extracted active (bleaching) clay can be dumped without harming the environment, and provision must be made for dumps at the planning stage. Non-extracted active clay can also be dumped without any direct environmental hazard, although there is the problem of odour as the oils contained degrade enzymatically thereby producing, amongst other things, sensorily active fatty acids which give off a rancid odour. The proportion of active clay used is around 3 - 5 percent by mass in relation to the crude oil used.

During the subsequent steaming process, odorous substances (aromatics) and flavourings and approx. 20 - 100 kg of fatty acids per tonne of oil are stripped (at 180 to 270C under a light vacuum of 4 to 10 mbars) by steam distillation. The steaming vapour is first fed through separator devices, such as hydrocyclones (centrifugal separators) to remove the oil droplets entrained with it and the fatty acids, and then condensed by direct contact with cooling water and recirculated. Using this method, only small quantities of wastewater are produced and they can be treated biologically with a maximum fat quantity of 20 - 25 mg/l wastewater. The oil-contaminated fatty acids can in turn be processed further in soap factories for soap production or in the chemical industry to manufacture other products.

2.3.6.2 Chemical refining

In the chemical process, the crude oil is first degummed and then immediately neutralised in one process stage. First, phosphoric acid (or more recently citric acid) is added to degum the crude oil by precipitating the protein. Then, in contrast to the physical separation, the acidic crude oil - acidic due to the free fatty acids it contains (2 - 10%, depending on the oil-seed and storage conditions) and the citric or phosphoric acid added - is neutralised by the addition of lyes, usually soda lye. This yields a mixture of neutralised oil, mucilages and soapstock.

After separation, the crude oil obtained is bleached and steamed as in physical refining. The same by-products are also produced, although the active clay consumption is considerably lower. Moreover, the steaming operation yields only about one tenth of the oil droplets and fatty acids obtained in physical refining.

2.3.6.3 Processing of soaps and mucilage

Disposal problems are associated with the processing of soapstock and mucilage. The soap is first boiled and separated with sulphuric acid (to break up the emulsion). This produces fatty acids which can be separated from the acid solution in settling tanks. The acid solution is then neutralised and cooled with slaked lime. Organic substances should be separated by mechanical or biological processing, and the remaining wastewater must comply with the following conditions for drainage (standard German values as a guide):

- **maximum temperature 35C**

- max. sulphate content due to addition of sulphuric acid 600 mg/l.

The quantity of wastewater from chemical wet neutralisation and the subsequent soapstock fractionation is around 0.5 m^3/t of initial product under modern production conditions. This is only equivalent to about 5% of the total wastewater from a refinery, but because of the high organic content and consequently the much higher Chemical Oxygen Demand (COD), this alone amounts to 50 - 60 % of the admissible total COD load of a refinery in Germany. The discharge of wastewater must therefore be inspected to ensure compliance with the relevant limit values.

2.3.6.4 Comparison of physical and chemical refining based on environmental factors

Wastewater quantities from neutralisation, particularly where there is a preliminary condensation vapour stage, can be considerably reduced by the use of the physical distillation process. However, this process, compared with the chemical refining process, consumes a far higher quantity of active (bleaching) clay. For reasons of economy therefore, chemical refining is popular although - as described above - it is characterised by the generation of large quantities of heavily contaminated wastewater which requires checking at the point of discharge into sewers and/or natural bodies of water to ensure that limit values are observed. Physical refining is preferable to chemical refining as active clay has a lower environmental impact.

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3. Notes on the analysis and evaluation of environmental impacts

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3.1 Air

Limit values for air pollution are laid down in Germany by the guidelines of the *Technische Anleitung zur Reinhaltung der Luft* (*TA-Luft* - Technical Instructions on Air Quality Control), and comply with the *Bundes-Immissionsschutzgesetz* [*BImSchG* - Federal Immission Control Act]. Further reference material is to be found in the *Richtlinien des Vereins Deutscher Ingenieure* [Guidelines of the Association of German Engineers VDI] for maximum immission concentrations [MIK] which are concerned with the establishment of limit values for certain air contaminants.

Under the terms of TA-Luft, the dust emission for organic substances in industrial plants may not exceed 50 mg/m^3 air at a mass flow of 0.5 kg/h. The waste air from extraction today may not contain more than 150 mg hexane/m^3.

3.2 Noise

Where noise levels are over 70 dB(A), noise-reducing measures such as hearing protection (ear muffs etc.) or silencing devices on machines must be provided. For comparison: leaves rustling in the wind produce a noise level of 25 - 35 dB(A) and normal conversation ranges from 40 - 60 dB(A). Years of exposure to around 85 dB(A) or more during most of a person's time in work is deemed damaging to the hearing at the workplace. It is, in fact, just as harmful to be exposed constantly to a uniformly low noise level as to a correspondingly higher one for a short time.

In Germany, the *Technische Anleitung zur Lrmbekmpfung* [*TA-Lrm* - Technical Instructions on Noise Abatement] establishes principles for noise protection and approximate emission values. The following approximate atmospheric immission values27) apply to:

27) Immissions are the effect of air-borne contaminants, vibrations, radiation and noise on humans, animals, plants and property (e.g. buildings).

- **areas containing mainly commercial premises: daytime 65 dB(A), night 50 dB(A),**
- **areas containing mainly residential accommodation: daytime 55 dB(A), night 40 dB(A).**

It should be borne in mind that noise immissions inside buildings can have more damaging

consequences because of building materials and methods used, in which case the values should be assumed to be correspondingly lower.

3.3 Wastewater

In crude oil refining, a wastewater quantity of 10 to 25 m^3/t initial product must be assumed (see Table 3, details from Germany's 4. AbwVwV). The following are the principal constituents of the wastewater:

- **sodium sulphate or sodium chloride**
- **calcium phosphate**
- **fatty acids (in part as calcium soap)**
- **mono-, di- and triglycerides**
- **glycerin**
- **protein**
- **lecithin**
- **aldehyde**
- **ketones**
- **lactones**
- **sterines.**

A refinery's wastewater output can be reduced by up to 90% if the vapour cooling water is

managed in a circuit - a system however, which results in higher COD concentrations in the circuit water. The minimum requirements for the final discharge of refinery wastewater must take account of this circumstance. However, despite the higher COD concentration where the cooling water is managed in a circuit, there is an overall general reduction in pollutant load. Biological wastewater treatment cannot yet be described as the most modern state-of-the-art process in view of the land required, the higher energy consumption and the problem of sludge disposal.

In Germany, the *4. Allgemeine Verwaltungsvorschrift* [*4. AbwVwV* - 4th General Administrative Regulation] establishing minimum requirements for the discharge of wastewater from oil-seed processing and fat and edible oil refining applies with regard to wastewater control.

Table 4 indicates the minimum requirements imposed on the wastewater. In works with biological wastewater treatment, a 5-day biological oxygen demand (BOD_5) of 25 mg/l and a chemical oxygen demand (COD) of 100 mg/l is prescribed28).

28) BOD_5 stands for the biological oxygen demand which is required by microorganisms in a five day period for the processing of organic substances in industrial water. In the case of COD, the quantity of oxygen produced by an oxidant to oxidize organic substances in wastewater is calculated.

Table 4 - Minimum requirements of the 4.AbwVwV

Parameters	Quantity of contaminated water	Settleable solids	COD			Extractable substances
Dimension	m3/t (1)	mg/l	mg/l*)			mg/l*)
Type of sample		random sample	2h	24 h	2 h	24 h
Oil-seed processing	10	0.3	200	170	20	20
Crude oil refining for edible oil production	10	0.3	250	230	50	40
	10 - 25	0.3	200	170	30	20
Analysis process		DEV H 2.2 (2)	Appendix to 2. AbwVwV of 10.01.80 (3)			DEV H 17/18-1
Analysis of		Single	Single value or mean			

measured values		value or mean value (4)	value

***) Within 2 or 24 hours**

(1) Initial product

In crude oil refining for the production of edible oil and edible fat, the following initial products are used:

- **crude oil, produced in the oil extraction process**
- **reject and reprocess batches passing through the refining process once again.**

(2) German standard process for water testing.

(3) If the value specified for settleable solids are exceeded in a single sample, 0.3 ml/l can be used to obtain the arithmetical mean if the dry mass of the filterable substances (DEV H 2.1) does not exceed 30 mg/l.

(4) Analysis of the precipitated sample.

The values given in Table 5 should apply for the discharge of acid solutions from soap fractionation.

***Table 5* - Limit values for the discharge of acid solutions from soap fractionation**

Quantity	0.3 m3/t oil
Maximum temperature	3C
pH value	6.0 - 9.0
Settleable solids which can precipitate in 30 mins.	10 mg/l
Fat	250 mg/l
SO_4	600 mg/l

Generally speaking, oil processing is linked to a laboratory in which checks are constantly carried out using a standardised measuring procedure. COD, BOD, special waste requiring disposal, dissolved solids and the oils and fats should be constantly tested for content. Regular temperature checks should also be carried out in situ.

In addition, the World Bank gives the following information relating to the wastewater in question here:

- In principle cooling water should not be discharged; if it cannot be recycled in the circuit, it should only be discharged if the temperature of the water into which it is

released does not rise by more than 3C,

- The pH of the wastewater and liquid waste should be kept constant between 6.0 and 9.0,

- The BOD value of the wastewater should be less than 100 mg/l,

- The COD value of the wastewater should be less than 1000 mg/l,

- The dissolved solid content of the water should be less than 500 mg/l,

- Additional preservation and storage facilities and areas should be kept available in case of accidents resulting in leaks of solvents, lyes and acids. Equipment should also be kept to hand to deal with any such accident situations.

3.4 Waste

Types of waste defined in 2 of the German *Abfallgesetz* [Waste Avoidance and Waste Management Act] are determined for oil- and fat- producing facilities in the ordinance on the determination of waste and residues *Verordnung zur Bestimmung von Abfllen und Reststoffen.* Waste types are further qualified by waste codes in accordance with the information bulletin entitled "Abfallarten der Landesarbeitsgemeinschaft Abfall" [LAGA - Waste types of the state working group on waste]. Waste groups 52 (acids, lyes, concentrates) and 55 (organic solvents, dyes, varnishes, adhesives, fillers and resins) are relevant.

3.5 Soil

Soil contamination problems in the production of vegetable oils and fats only occur in connection with improper disposal of waste and wastewater (see also sections 3.3 and 3.4).

3.6 Choice of site

The following is to be borne in mind when choosing a site:

- The plant or plant complex should not be sited near ecologically sensitive habitats (marshlands, protected areas, national parks etc.).
- Local resource protection agencies or authorities should be involved at an early stage in the selection of the site or alternatives.
- Because of the odour nuisance, the plant should not be sited in the immediate vicinity of residential areas. Generally speaking, plants should be sited on high ground above the local topography; the sites should not constitute areas through which air passes and the prevailing wind currents must not affect populated areas. Local climatic and meteorological studies can be used to obtain useful information.
- The plant or plant complex should be built close to surface water (preferably flowing water), and this water must have the maximum dissolving and absorption capacity for wastewater.
- At the site it should be possible to recycle wastewater - following minimal treatment - for agricultural and industrial purposes.
- The plant should only be built in a municipality if the production wastewater can

be treated in the municipal sewage system.

Processing facilities for fruit are sited in the actual growing areas as the crop has to be processed immediately after harvesting. Economic processing capacities in industrial countries start at 15 to 20 t feedstock per day.

Oil-seeds and nuts are transported in some cases over long distances to the processing industries. Processing capacities for pressing plants start at around 200 t/day, and those of solvent extraction plants at around 100 t/day. In highly industrialised countries, however, capacities of 1000 to 2000 t/day are commonplace. Refineries can operate economically from 50 t/day but plants in industrialised countries have processing capacities of 100 to 300 t/day. The question to be answered when deciding on the capacities to be installed is whether it would be preferable (for reasons of environmental protection and employment) to have small, decentralised plants rather than one large plant. Wastewater and waste air treatment systems and likewise waste disposal can also be organised decentrally as can the operation of a test laboratory.

3.7 Transport

Decentralised processing can obviate the need - as sometimes happens in view of the amount of traffic to and from large plants - to rethink local transport routes and traffic plans, and can avoid the associated noise, air pollution and traffic jams, as well as the risks to pedestrians from heavy goods traffic transporting raw materials or products to or from the

plant. A transport sector and traffic study should be produced for route selection and for the analysis of problems and possible remedies.

4. Interaction with other sectors

Oil-cake or meal are by-products of crude oil production and are frequently processed further in the same plant to make animal feed (see environmental brief Livestock Farming).

As soap and fatty acids are produced in the refining process, a soap factory can be built alongside the plant. This eliminates problems with the sale of fatty acids or the fractionation of the soapstock (acid solutions). Likewise, the production of edible oil or edible fat in the refinery can be linked to the production of baking or cooking fat, shortenings or margarine.

Filling installations are often linked to refineries as edible oil and edible fat are now sold almost exclusively in a packaged form. The linking of filling installations to refineries is advantageous as the oils and fats are packed immediately and so have no chance of becoming rancid, and plant wastewater produced during the filling process can be treated and disposed of with the wastewater from the refinery (see environmental brief Wastewater Disposal).

Steam is required to produce and refine vegetable oils in small and large plants, thus oil mills

or refineries often operate their own steam production plant. National provisions for large furnace installations must be observed in this regard (in Germany: the TA-Luft).

5. Summary assessment of environmental relevance

5.1 Crude oil extraction

In the extraction of vegetable oils from fruit and seeds, the cleaning, crushing and conditioning operations generate dust which it must be possible to remove with centrifugal cyclones. Dust is also produced when meal and press cake are made and it must be possible to remove it in the same way.

As this dust is of vegetable origin, it can be biologically degraded without the need to take any technical environmental protection measures (small plants), or it can be used as fertiliser (castor-oil seed meal). Production plants should not, however, be sited close to populated areas. The same is true of the larger quantities produced by large-scale plants in which the dust, after extraction, must be collected and dumped in a well-organised manner.

When oil-bearing fruits are extracted and boiled, large quantities of waste-water are produced which can be degraded biologically, albeit at the expense of a high oxygen consumption. For this reason, mechanical pre-cleaning is necessary - an operation in which

sediments are precipitated and removed from time to time.

All oil mill wastewater should be fed through oil separators as larger quantities of wastewater containing vegetable oil cause the formation of a thin film of oil on bodies of water which interferes with the oxygen supply. Wastewater with an excessively high oil content must also pass through a biological treatment plant in which organic substances can be degraded by constant aeration (oxygen supply).

Extraction processes produce wastewater which can contain solvents. Measures must therefore be taken to ensure that the maximum solvent discharge into the environment is not exceeded.

5.2 Crude oil refining

Large quantities of falling water are produced in the refining of crude vegetable oils and fats and these are passed through oil separators for disposal. The water is fed back into the refinery after passing through a recooler. Excess falling water can be discharged into the surrounding water once it has passed through a biological treatment plant in which organic substances are degraded.

When soapstock is separated into fatty acids, acid solutions are produced which can no longer be used in the circuit. Before their discharge into treatment plants or water, they must be specially treated (neutralised) as they are acidic and contain - in addition to fat and

mucilaginous substances - sulphate ions, which must not exceed certain values as they lead to salination of the wastewater and can destroy concrete drainage pipes.

A 100% reduction in wastewater and pollutant discharges into surface water is considered to be feasible if one of the following measures is taken:

discharge by spraying
discharge by other irrigation systems
drainage into settling tanks
drainage into municipal and urban sewage treatment systems.

In oil and fat production, the environmental pollutants formed and released in waste air or wastewater depend largely on compliance with technical tests and countermeasures for environmental safety purposes. Constant supervision of normal plant operation is essential to ensure that limit values are observed in terms of pollutant removal. Personnel is to be appropriately instructed in the framework of continuous training and upgrading. Training and preparation campaigns aimed at women are recommended for environmental protection jobs.

In view of the potentially serious negative implications for the environment and health in large plants in particular, the appointment of safety, environmental protection and works officers should also be demanded and the women concerned should be involved in the selection process.

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56. Sugar

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1. Scope

Sugar is the only food extracted from two different plants - the sugar beet (beta vulgaris) and the sugar cane (saccharum officinarum) - which grow in different regions. Competition between these two international cash crops only arises in small border areas where both are considerably below their physiological optimum, usually latitude 25 to 38 degrees north. The main sugar beet growing areas are located in the temperate climate of Europe and North America in regions with average mid-summer temperatures of 16 to 25C and an annual rainfall of at least 600 mm, but sugar beet is also grown in the sub-tropics in the winter months. Irrigation is essential where the rainfall is less than 500 mm. Beet thrives best on deep loamy soils with a neutral to weakly alkaline reaction, and in intensive farming requires adequate mineral compound fertilisation. Since beet can only be grown in the same field every fourth year to ensure a healthy crop (avoiding, for example, beet nematode, the main cause of the disease known as beet sickness), the catchment area of a sugar beet factory is very large. The vegetation period is generally five to six months, with yields in a temperate climate ranging from 40 to 60 t/ha, and in the sub-tropics averaging 30 to 40 t/ha. The sugar content ranges from 16% to 18%. Sugar cane grows in tropical lowland climates, and is farmed almost exclusively between latitude 30 south and 30 north, and particularly between the north and south 20C isotherms. Besides intensive sunlight, a rainfall of at least 1,650 mm or irrigation is essential. Heavy, nutrient-rich soils with a high water capacity are preferred;

pH values in the weakly acidic to neutral range are best. Nutrient requirements are high due to the huge mass production. Pest and disease attack have been reduced by resistance breeding and plant development, with biological pest control playing an increasingly important role. Sugar cane is suitable for monoculture and is indeed mainly grown as such. Plant cane is generally harvested after 14 to 18 months, and the new growth (ratoon) after 12 to 14 months. Yields are from 60 to 120 t/ha; the sugar content is on average 12.5%. Harvest quantity and sugar content decline as stocks age, with the result that the total useful life does not normally exceed 4 to 5 harvests.

Sugar factories are agro-industrial centres which contract out the cultivation of their raw material or, alternatively, grow it themselves, have their own energy and water supplies and large, varied workshop complexes. The plant installed is designed to handle a single natural raw material. Where used for direct processing of the harvest, the seasonal processing period coincides with the period of use of the sugar production plant. New plants process between 5,000 and 20,000 t daily (24 hr), although in order to handle 10,000 t/day, sugar production plants must have an appropriate infrastructure. The production plant should be situated wherever possible in the centre of the cane or beet growing area, it should be close to water and should be connected to the public railway and road networks. The by-products arising during sugar manufacture - molasses, sliced beet and cane bagasse - are either used or processed further in the plant, or alternatively form the raw materials for other industries.

Harvesting, storage and cleaning of the raw material

Sugar beet is harvested almost exclusively mechanically while sugar cane in contrast is harvested largely manually (cutting of stalks). The raw material is then transported to the factory by rail or road. Exceptionally, sugar cane is transported by water. Sugar beet can be stored for one to three days, depending on the temperature and method of storage, whereas sugar cane cannot be stored and must be processed immediately after harvesting or in any case no more than 12 hours later; sugar losses of up to 2%/24 hr are possible. Sugar beet is always washed before processing, but sugar cane is usually only washed if it has been harvested by machine.

Cutting, crushing and extract purification

Sugar beet is chopped in slicing machines, and sugar is extracted from the slices in the countercurrent with water at 60 - 70C in an extraction plant; the water is then removed mechanically and before drying the extracted beet is usually mixed with up to 30% molasses, normally made into pellets and used as animal feed. Because of their residual sugar content (approx. 0.8%), the slices - after drying - can be used as silage (preserved by fermentation) and as an agricultural feedstuff.

Sugar cane is prepared by revolving knives, crushers and/or shredders and then the juice is extracted in four to seven rollers in line or is extracted like sugar beet in a diffuser. A fibrous residue (bagasse) with a low sucrose content is produced at a rate of 25 to 30 kg/100 kg cane. The fibre content is approx. 50%/bagasse.

Extract purification

Beet and cane are processed in a very similar way after the raw juice has been extracted. The raw juice is purified mechanically and chemically. First fibre and cell particles are removed mechanically, then the juice is purified chemically by precipitation of some of the nonsucrose substances dissolved or dispersed in the juice, and the precipitate is then filtered off. In the beet sugar industry, repeated precipitation with calcium carbonate has proved successful, an operation in juice purification where lime and carbon dioxide are introduced into the juice at the same time. Synthetic flocculants, in particular polyelectrolytes, improve particle agglomeration and reduce sedimentation times in the decanter from the normal 40 - 60 minutes to 15 - 20 minutes. In the cane sugar industry, simple liming (defecation) is usually employed as the extract purification process, lime/sulphur dioxide treatment (sulpho-defecation) being less common and lime/carbon dioxide treatment rare. The decantate is then finely filtered for a second time and goes directly to the evaporation station. The sediment or sludge concentrate (approx. 25 to 30 kg/100 kg raw material) is usually separated in rotary vacuum filters into filtrate and filter sludge/cake (approx. 3 to 6 kg/100 kg raw material), the filtrate returned to the process and the filter sludge separated.

Evaporation and crystallisation

The clear juice (from 12 to 15% dry matter/dry sugar content) is continuously concentrated by multiple stage evaporation until it has a dry content of 60 to 70%, each stage of this

process being heated with the steam (steam-saturated air released when the clear juice is concentrated) from the previous stage. In the boiling process, more water is removed from the concentrated juice (syrup) in boilers operating at an approx. 80% vacuum. The juice is boiled at a lower temperature than normal because of the low pressure in the equipment, thus preventing any discoloration due to caramelisation. When a certain ratio of sugar to water (supersaturation) is reached, crystals form. By adding more syrup and evaporating more water, crystallisation continues under controlled conditions until the required crystal size and quantity are obtained. The boiling process is then complete and the resulting boiled mass, now called massecuite, is drained from the vacuum pans into crystallisers. As the massecuite is constantly cooled, the supersaturation changes, causing the sugar crystals to grow once again. The massecuite is then transferred from the crystallisers into centrifuges, in which the crystallisate is separated from the syrup, leaving behind the yellowy brown raw sugar. The centrifuged syrup is boiled to form a massecuite once again and the crystallisate obtained from it is centrifuged. The syrup produced from the centrifuging is called molasses. If, when the massecuite is centrifuged, the crystallisate is cleaned of the residual syrup still attached to it by a water and/or steam jet (affination), white sugar is extracted in just one process from beet or cane. In refining (recrystallisation), a plant-intensive technology, raw sugar and poor quality white sugar are dissolved, and then decoloured and filtered by the addition of activated carbon or bone char, or ion exchange resins. Refined sugar, which meets the most exacting requirements in the sugar processing industry, is extracted from the subsequent crystallisation process. The quantity of molasses produced ranges from 3 to 6% of the raw material fed in, depending on the technological quality of the raw material and

the end product. The sugar content of the blackstrap molasses is around 50%.

Storage

The sugar extracted is cooled and dried before storage or packaging. It can be stored loose, packed (1 kg) or bagged (50 or 100 kg). The essential factor for proper storage is a relative humidity of around 65% in the store. This is approximately the point of equilibrium between the absorption and the release of moisture from the sugar crystals.

2. Environmental impacts and protective measures

Typical environmental impacts caused by sugar manufacture are due to:

- **wastewater from beet and cane washing, the boiler house (boiler blow-down water) and extract purification in the evaporation and boiling station (excess condensate and purification water), refining (regeneration water from the ion exchange resins), the manufacture of alcohol, yeast, paper or chipboard (where molasses and bagasse are further processed in the plant), site cleaning and rainfall;**
- **emissions into the air from the boiler plant (flue gases from processes in which solid, liquid and gaseous combustibles are burnt), airborne substances (soot and flue ash), raw material processing, extraction, juice purification and juice**

concentration (ammonia) and from biochemical reactions of organic wastewater components in lagoons (ammonia and hydrogen sulphide);
- solid waste from raw material treatment (earth, plant remains), the steam generator (ash) and extract purification (filter sludge).

2.1 Cultivation, harvesting, storage and cleaning of the raw material

Because of the demands placed on it, the soil is heavily polluted due, in particular, to many years of single-crop agriculture (sugar cane), the main pollutants being:

- the fertilizer and pesticide feed,
- adverse effects on the natural cycle due to soil compaction and salination, dehydration and microorganism decimation.

Precautions in agriculture:

- growing not to be allowed in marginal soils
- examination of soils for chemical and physical properties, water-retention capacity, drainage properties and workability (important where crops need to be irrigated),
- fertilisation to be in line with crop requirements in terms of time and quantity,
- checking of pesticides for suitability for targeted pest control and establishing of a precise dosing concentration and quantity,

- observation springs to be made for the constant monitoring of groundwater and any changes to it.

The environmental effects caused by the harvesting and transport of the raw material are basically air pollution from the burning of sugar cane fields (flue ash) and contaminated access routes. Clarification agents containing lead (lead acetate solution) should no longer be used for the polarimetric sugar analysis of beet and cane extracts; instead the environmentally friendly reagents aluminium chloride or sulphate alone should be used.

Odours are rarely a nuisance in beet storage, occurring more frequently with sugar cane especially where it is stored for more than one day. Sugar beet is normally supplied with 10 to 20% moist dirt attached. In dry seasons, this percentage can be under 5% but can be over 60% in times of frequent and prolonged rainfall. Accordingly, the quantity of suspended solids in a flotation and washing operation, where some 750% water on one beet can be assumed, can range from around 7 to 80 kg per m^3 water. The water pollution, after one operation, stands at around 200 to 300 mg BOD_5/l, although this value can rise to over 1,000 mg/l if larger quantities of sugar and other beet components should transfer into the flotation water. Washing and flotation water are today kept in a closed circuit, continuously purified in basins with mechanical sludge removal and cleared of plant fragments using narrow-mesh sieves. The recycling of the flotation and washing water reduces the wastewater quantity to around 30 to 50% in the case of beet. This reduction in quantity means that wastewater treatment is at last a feasible option. The earthy sludge concentrate

produced is deposited, wherever possible, in dips, boggy soils and lowlands which can then be put to agricultural use. The water is kept at a pH of about 11 using waste lime from lime kilns so as to prevent any odour nuisance due to microbial activity in the flotation water.

The burning of sugar cane before harvesting is still common practice, its only advantage being that it facilitates manual harvesting, as all the dry parts of the plants are removed by burning and the harvest volume is thereby considerably reduced. Cutting speed and thus earnings per worker are higher as the piece work pay is not based on harvested weight but unit of length/row. The drawbacks are the adverse effect on cane quality due to damage to the cell tissue and thus increased risk of infections at points of damage, destruction of organic matter, damage to the soil structure due to increased drying, increased soil erosion particularly on hilly sites, and finally air pollution in the form of fumes and flue ash emissions. Sugar cane field burning would therefore seem to be contraindicated for biological and ecological reasons.

The level of contamination of the harvested crop depends directly on the harvesting technique and soil and weather conditions during harvesting. Hand-cut cane can contain between 7 and 20% foreign matter, while the percentage weight when mechanically harvested is 3 to 5%.

If the cane is washed, one can estimate 3 m^3 to 10 m^3 washing water/t (fresh water, excess condensate, hot well water and recycled washing water).

If cooled excess condensate and hot well water is not fed into the circuit, it can all be used for washing instead of fresh water.

In this way, both the factory's water consumption and the pollutant freight of its wastewater can be reduced. Depending on the washing system, the BOD_5 value can be anything from 200 to 900 mg/l. Foreign matter could be removed by pneumatic dry separation to obviate the need for cane washing. The sludge concentrate is treated and the odour nuisance prevented in the same way as in the beet sugar industry.

2.2 Raw material cutting, crushing and extraction

Noise nuisance is produced by the high-speed slicing equipment for sugar beet and in the whole area of mill extraction (sugar cane). Individual ear muffs are required. Dust is generated with particular intensity in the area of sugar cane intake and transfer to the mill tandem. No direct hazard to personnel is caused where these operations are automated.

The intermediate products of the sugar industry are ideal nutrient media for a large number of microorganisms. The whole range of activities, ranging from the preparation of the raw material through to crystallisation, also provides a promising culture medium. The risk of microbial contamination is particularly high in extraction, where not even the most stringent technical hygiene measures and optimum process management can obviate the need to use disinfectants. Repeated high-pressure steam disinfection at the points in the mill tandem

most at risk (links in the chain and connecting elements) is only about 60% as effective as biocides. A chemical treatment can also be used during mill operation, while steam treatment can be effectively applied when the mill is not working. Major disinfection operations can lead to heavy sugar losses and are therefore not economically viable. The substance most frequently used to disinfect extraction plants is still formalin (approx. 35% aqueous solution of formaldehyde). It is added in batches at a concentration of around 0.02 to 0.04% in relation to the quantity of raw material processed. The formaldehyde concentration in the juice decreases constantly throughout the subsequent process stages. In the clear juice, levels are less than 1 mg/kg while only traces can be found in the syrup and concentrations of around 0.10 mg/kg in white sugar. It is nonetheless clear that, however it is used, formaldehyde is removed from the sugar to the extent that the technically unavoidable residues are rendered harmless. Traces of formaldehyde are also found in the condensates which are produced from evaporation and which are returned to the factory's water circuit. Formalin is controversial in the light of the carcinogenic effect attributed to it, but is still the preferred disinfectant in extraction. Alternative substances, e.g. thiocarbamate, quaternary ammonia compounds, cresol derivatives, hydrogen peroxide and the like, have all been tested over recent years. Their effectiveness as disinfectants when used in extraction plants is comparable to that of formalin. Thiocarbamate, cresol and hydrogen peroxide - like formalin - are also removed by the extraction water during the process, thus only traces can be found in the extracted slices. Quaternary ammonia compounds, by contrast, are irreversibly adsorbed or precipitated along with other organic substances during extract purification.

2.3 Extract purification

The filter sludge produced in sugar factories has a dry content of 50 to 60%, up to three quarters of which is in the form of calcium carbonate, depending on the juice purification process, the rest consisting for the most part of organic substances. In beet sugar factories, it is usually pressed to a dry content of at least 70%. Because of its phosphate and nitrogen content, it is used mainly as fertilizer and instead of lime for soil neutralisation. In cane sugar factories, the sludge is either passed on to farmers or spread directly on to the factory's own fields. The high protein content in the dry cane filter sludge (14 to 18%) means that it can be used as supplementary fodder in cattle farming. The solid content is separated in almost all cases by continuous filtration through rotary filters and secondary filtration using precoated filters. The quantity of wash water produced is so low that it can be disposed of with the filtrate.

The auxiliary substance most frequently used in extract purification is lime (CaO). Depending on the purification process used, consumption ranges from around 0.75 kg CaO (defecation) to 20 kg per tonne of raw material (two-stage calcium carbonate precipitation). Lime and carbon dioxide is obtained from limestone in the coke-fired shaft furnaces of beet sugar factories. It is not economical for cane sugar factories to produce their own burnt lime because they need such small quantities of it. The CO_2-rich gas produced in lime burning consists of around 35 to 40% CO_2, the rest being N_2. If the oxygen supply is inadequate, carbon monoxide (CO) may be produced. Since the combustion temperature is below 1,200C,

no nitrogen oxides (NOx) are formed. The washing water (8 to 10 kg/kg limestone) produced during gas purification is not organically loaded. The crushing of burnt lime is associated with the generation of large quantities of dust, necessitating the use of dust separators. Breathing apparatus must also be worn by personnel working in the immediate vicinity of the lime kiln, particularly personnel involved in cleaning work.

2.4 Evaporation, crystallisation and sugar drying

Some 4 - 6 m^3 cooling water/t raw material - depending on whether single or central condensation is used - is required to condense the steam from the last vessel of the evaporation plant and the evaporation crystallisers. In the cooling water circuit, the mixed condensate (hot well water) produced from the condensers (steam condensation) at 40 to 50C must be recooled to 20C maximum in cooling towers, grading houses or evaporation lagoons (mist formation) so that it can be reused. The level of pollution of the condensate produced is determined by the technical conditions in the evaporation and boiling station and the condensation plant. Organic pollution and sugar losses in the mixed condensate can be kept very low where correctly designed juice separators are fitted, with values of around 30 to 150 mg/l BOD$_5$ in raw sugar factories (cane processing) and 5 to 15 mg/l in the beet sugar industry of today. Incrustations are removed from evaporator pipes and other hot surfaces by cleaning with an approx. 5% soda solution followed by a 2 to 5% hydrochloric acid solution. The acids and lyes used for cleaning can be neutralised and fed into the water circuit.

Sugar dust from sugar driers or defective dust-extraction systems can give rise to severe air pollution. This is not only a health hazard but, at a grain size of < 0.03 mm, also highly explosive if the dust/air mixture concentration is within the explosion limit (approx. 20 to 300 g/m^3). A low dust level is 2 g/kg sugar. Dust is separated in dry electro-filters or in wet dust-extractors (scrubbers). If no dust separators are installed (e.g. older white sugar factories), breathing masks must be provided. The concentration must be kept low by means of adequate ventilation and precautions must be taken to prevent ignition of the explosive atmosphere (smoking ban, no repair work which produces frictional heat or sparks, installation of explosion-proof electrical systems) in order to minimise the risk of explosion.

2.5 By-product manufacture

Dry slices: the water obtained from the mechanical drying of the extracted beet slices is recycled in the extraction process. The slices are mostly dried in drum type driers (700 to 900C) to a dry content of 25 to 90%. The mixture of combustion gas from natural gas or oil plus flue gas from steam production is used as the drying gas. A waste gas quantity of 1.5 to 4.5 m^3/kg extracted slices - depending on the drying system used - must be expected. The dust content of waste gases from the drier depends, inter alia, on the quantity of molasses added and process management (temperature, holding time). The dust concentration in the untreated gas ranges from 2 to 4 g/m^3. Similar dust concentrations may also arise after the cooling drum, the pelleting station, the bagging plant and the pneumatic conveyors. The

total carbon concentration ranges from 300 to 1,200 mg/m^3, depending on process management. The SO_2 concentration after the slice drying plant depends, inter alia, on the fuel used, the drying process and slice composition. SO_2 concentrations of up to 1,000 mg/m^3 in the waste gas have been encountered.

Sugar extraction from molasses: more sugar can be extracted from the molasses if additional expenditure is allowed for operating costs and equipment. The regeneration- and wash water then produced is heavily contaminated and must be handled separately if the chloride concentration in the total wastewater exceeds 2,000 mg/l.

Biotechnical processing of molasses : the biotechnical recycling of beet molasses almost always takes place in different plants; in contrast, it often forms part of a sugar factory and also gives rise to high wastewater loads. Yeast, ethanol, citric acid and much more can be produced from molasses by fermentation. The waste load remaining from baker's yeast manufacture is around 156 kg COD/t molasses or 187 kg/t baker's yeast. The distillation residue (vinasse) which remains is highly diluted (aqueous) (up to 96% water) and can be used as cattle feed (approx. 50 l/day and animal). As these difficultly biodegradable substances cannot be removed by economically feasible treatment processes, the process wastewater from yeast manufacture has to be thoroughly biologically treated, and then recycled for agricultural use where possible. However, even after biological treatment, the process wastewater must not be discharged directly into the drains. Since the climatic

conditions of sugar-cane-growing countries favour eutrophication processes, stringent requirements must be laid down with regard to wastewater purification.

2.6 Energy supply

Some 300 to 400 kg steam and 35 to 40 kWh electrical energy is required to process 1 t beet to white sugar. Every factory must be equipped with steam and electrical energy generation plants (heat/power linkage). Oil, gas and coal are used as primary energy sources and waste gas purification is essential where emission limits are exceeded.

The steam and electrical energy requirement for sugar cane processing (to drive the roller mill with steam turbines) stands at around 550 kg steam/t cane (raw sugar production) or 615 kg steam/t cane (white sugar production) and 35 to 40 kWh electrical energy/t cane. The mean calorific value of bagasse (approx. 50% moisture) is around 8,400 kJ/kg (mean calorific value of oil around 42,000 kJ/kg). The bagasse produced is sufficient to cover the factory's energy requirements. Incomplete burning of bagasse (water content > 50%) increases the emission of flue ash and carbon particles.

To start up the factory (start of campaign), other energy sources have to be used. If a refinery is also operated, it may also be necessary to back up the bagasse with other fuels. Maintenance firing is also essential where the plant is shut down for a prolonged period. A complete conversion to other energy carriers is essential where bagasse is used as a raw material for paper or chipboard manufacture.

2.7 Water management

There is no stage in sugar production where water in some quantity is not required. The technical water requirement of the sugar extraction process in a beet factory is around 20 m^3/t beet. The amount of process water introduced can be reduced to 0.5 m^3/t by the introduction of water circuits. For practical reasons, highly contaminated (transport, purification, regeneration, hot well water) and slightly contaminated (turbine cooling, pump cooling, seal and gas scrubbing water, condensate excess) water circuits should be kept separate, as water with a low level of pollution (in Germany < 60 mg/l COD or 30 mg/l BOD_5) can be drained into receiving streams. In a well-managed factory, the quantity of highly contaminated wastewater produced can be reduced to 0.2 m^3/t beet; it should not exceed 0.5 m^3/t, beyond which the cost of wastewater treatment would then become uneconomic. Pollution rises in the course of the campaign, reaching COD values of 6,500 mg/l or BOD_5 values of 4,000 mg/l and more. In sugar cane processing, large quantities of cane washing water (up to 10 m^3/t) and mixed condensate are produced during steam condensation and raw sugar refining, which must be managed in a circuit system (large land areas required for evaporation lagoons, high investment costs for cooling towers). Cane washing water (260 to 700 mg/l BOD_5), filter residue (2,500 to 10,000 mg/l BOD_5) and washing water from decolorising carbon and ion exchange resins in refineries (750 to 1,200 mg/l BOD_5) are all heavily contaminated. The purification water also includes wastewater required for cleaning

the production areas and plant during and after the campaign, and for cleaning sugar transport vehicles. There are also juice and water overflows at plant breakdowns (clear juice, for example, has a BOD_5 of about 80,000 mg/l) so that values of up to 18,000 mg BOD_5/l can occur. Negligence is the main cause of excessive wastewater contamination. If a plant is carefully managed, this wastewater does not exceed values of 5,000 mg BOD_5/l. Low organic pollution and sugar losses in the mixed condensate (30 to 150 mg/l) can only be achieved by the installation of separators in the steam pipes.

The aim of establishing water management in a sugar factory must be to eject or treat as low a quantity of polluted water as possible. Water recycling heads the list of measures to be taken inside the factory. Water management must be such that, once closed circuits are established, unpolluted or only slightly polluted water requiring no further treatment is discharged into the drains.

The treatment processes for wastewater which can be carried out in sugar factories are largely determined by local factors. The management of the wastewater and circuit conditions inside the plant have a major effect on plant size and the level of degradation which can be achieved.

Wastewater treatment begins with the mechanical removal of suspended particles followed by aerobic treatment. The simplest and by far the most desirable treatment method for the processing of organically polluted, concentrated sugar factory wastewater is its collection in a

series of lagoons using an overflow system. The wastewater then purifies itself. The time required for adequate degradation of the wastewater in the lagoons is determined by the following factors:

- **height of water level in the lagoon**
- **lagoon area**
- **subsoil below the lagoon/adequate sealing against the subsoil**
- **weather conditions**
- **external flows of water.**

The lower the water level and the warmer the weather during the degradation processes, the faster the water in the lagoon is treated. Lagoon depth should not exceed 1.20 m in temperate climates, while 1.50 m is acceptable for subtropical/tropical zones (sugar cane growing). If there is a high level of evaporation, the content of the wastewater is concentrated; if there are external flows of water and rainfall is high, the lagoon wastewater is diluted. The treatment of wastewater with a concentration of 5,000 mg BOD_5/1, as is usual in the domestic sugar industry, requires a constant degradation efficiency of 99% or more to reach a BOD_5 value of 30 mg/l. At a lagoon depth of 1 m and a degradation period of 6 to 8 months, values of 100 mg BOD_5/l can be achieved, which is equivalent to partially biologically treated water. In sugar cane growing areas, complete biological purification - a BOD_5 of less than 30 mg/l - can be achieved within five or six months with good lagoon

management. This long-term process of degradation in lagoons could solve the wastewater problem for the sugar industry if sufficient lagoon area were available. The sugar cane processing industry, in fact, generally has sufficient land area available and so uses the lagoon process almost without exception.

Organic substances are degraded by both aerobic and anaerobic processes. In the anaerobic stages, fermentation and putrefaction occur, thus the possibility of odour nuisances, primarily due to the formation of hydrogen sulphide and butyric acid, cannot be ruled out. This drawback can be overcome, however, by selecting suitable locations and by adequate additional aeration. During the activated sludge process, oxygen is introduced into the water in the form of air via an aeration system.

Small-scale continuous systems operate with a substantially higher microorganism density and a higher oxygen supply, and achieve a degradation level of around 90%. Atmospheric pollution is clearly higher at 2 to 7 kg COD/(m^3/day) and the energy required for the air supply stands at around 3.5 kWh/(m^3/day).

Anaerobic wastewater purification plants consist of large tanks (around 3,000 to 7,000 m^3) in which anaerobic bacteria degrade the organic pollutants to form biogas (approx. 75 to 85% methane). This is particularly effective where wastewater is heavily contaminated. The organic content is 80 - 85% decomposed, with the remaining degradation taking place aerobically in the aeration system. The benefits of this process are that the methane gas can

be used directly as an energy source to heat the tanks and that the problems of odour can be overcome; an additional factor is that less space is required than in the case of lagoon systems.

Compared to the large quantities of sludge produced in the flotation and washing water circuit, and in some cases occurring in the form of lime sludge from juice purification, the quantities produced in wastewater conditioning are very low. Recycling is as for filter sludge (see 2.3). The form of "large-scale wastewater processing" most frequently used is overhead irrigation or, rarely, basin irrigation. The preconditions for this are level undrained areas, deep soils with no tendency to silting and a low water table (> 1.30 m). During the passage through the soil, the following processes take place:

- **mechanical filtration on the surface**
- **absorption of the dissolved substances by bacteria in the soil**
- **biological oxidation of filtered and adsorbed material by bacteria in the soil in the intervals between the individual doses of wastewater.**

Basin-irrigation is carried out mostly on small parcels of land surrounded by earth walls (so-called retaining filters). Mechanisation is severely restricted by parcel size and the earth walls. Only crops which grow vertically and which are not sensitive to overdamming are suitable, e.g. tree crops and meadow areas.

Sprinkler irrigation is the most expensive biological treatment process. All settleable solids

must be removed to minimise malfunctions in the sprinkler irrigation installations. The load should be intermittent and the quantity rained onto each area must remain small (< 500 mm/vegetation period - individual doses not exceeding 80 mm). If the wastewater is first treated in lagoons to at least 180 mg BOD_5/l, drained areas can also be irrigated if the water table is suitably low. In addition to wastewater treatment in the soil, the wastewater recycled for irrigation also acts as a fertilizer.

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3. Notes on the analysis and evaluation of environmental impacts

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3.1 Emission-limiting requirements

Two types of requirement are imposed on sugar factories: general and special. The provisions regarding general regulations to limit emissions contain:

- emission values, which current technology can keep to admissible levels,

- emission-limiting requirements conforming to the state of the art,
- other requirements to protect against harmful environmental impacts by air pollution and
- processes for determining the emissions.

The following general requirements are imposed:

- reduction in the quantity of waste gas by enclosing plant components,
- registration of waste gas flows,
- circulating air management and process optimisation through more efficient use of waste heat,
- waste gases must be released so that they are freely discharged without obstruction in the general airstream,
- chimneys should be at least 10 m above the ground and project 3 m above the roof ridge, but should be no more than twice the height of the building,
- in the field of wastewater treatment, including lagoons, anaerobic degradation shall be eliminated by technical or structural measures as far as possible.

The special requirements (e.g. in Germany in accordance with the TA-Luft [Technical Instructions on Air Quality Control]):

- the drum inlet temperature in sugar beet slice drying plants must not exceed 750C or equivalent measures to reduce odours must be applied,

- dust emissions in the damp waste gas must not exceed 75 mg/m^3(f),
- where solid or liquid fuels are used, the sulphur content by weight must not exceed 1 % in the case of solid fuels related to a net calorific value of 29.3 MJ/kg, or equivalent waste gas purification must be carried out.

A crucial factor in all emission considerations is the emission load resulting from the quantity of waste gas discharged from the chimney, multiplied by the pollutant concentration. This concerns primarily the load from sulphur, nitrogen oxide, carbon monoxide and dust.

The following emission limits apply to furnace installations with a furnace heat output of < 50 MW:

Emissions	**Unit**	**solid**	**liquid fuels**	**gaseous**
dust	mg/m3	50	80	5
CO	mg/m3	250	175	100
NOx	mg/m3	400	300	200
SO_2	mg/m3	2000	1700	35

Source: TA-Luft [Technical Instructions on Air Quality Control]

The emission values relate to an oxygen content by volume in the waste gas of 3% for liquid

and gaseous fuels. In the case of solid fuel, 7% applies where coal is used and 11% applies where wood is used.

Flue ash and soot are the main air pollutants where bagasse is used as fuel, but flue gases from bagasse do not contain any toxic substances. Where fuel oil is used in the cane sugar industry, a sulphur content of 0.5 to 1.0 % by weight in the fuel oil is permissible.

The main parameter of any biological treatment and in any watercourse is the biochemical oxygen demand (BOD). This is the quantity of oxygen in mg/l which is consumed by microorganisms at 20C within a degradation time of five days. The chemical oxygen demand (COD), on the other hand, is the standard for the content of oxidisable substances found in water, i.e. the method covers not only biologically active substances but also inert organic compounds. It is essential to use the COD method (evidence provided using potassium permanganate or potassium bichromate) as a fast method of determining the level of water pollution.

In its guidelines for the cane sugar industry, the World Bank takes the view that three parameters are of fundamental importance when it comes to assessing sugar factory wastewater pollution with biodegradable substances and their impact on the environment:

BOD_5 for determining the oxygen-consuming organic material;

TSS (total suspended solids mg/l) for establishing the total quantity of suspended matter

(primarily inorganic substances from cane and beet washing water);

pH as extreme pH changes are harmful to water fauna.

The minimum requirements regarding the pollution levels in wastewater to be released into bodies of water are based on the treatment processes normally applied in the various industries and must conform to the state of the art.

For sugar production and associated industries (including alcohol and yeast production from molasses) the following minimum requirements are specified in Germany (source: (1)):

	A cm^3/l random sample	**COD mg/l mixed sample**		**BOD_5 mg/l mixed sample**		**(TF) random sample**
Seal and cond. water	0.3	60	--	30	--	--
Other water	0.5	500	450	50	40	4

A = volume of suspended solids

TF = toxicity to fish, expressed as the minimum dilution factor of the wastewater at which all test fish survive under standardised conditions within 48 hours.

These values apply to random samples in the case of lagoons.

Due to local circumstances it may be necessary to limit other parameters for discharging into watercourses, e.g. temperature, pH, ammonia, chloride.

In the USA, the Environmental Protection Agency (EPA) has imposed limit values for cane sugar factories (raw sugar factories and refineries).

General limit values regarded as "best available technology economically achievable" (BATEA or BAT) are:

		BOD_5	**A**	
Raw sugar factory	(kg/t cane)			
max.daily value		0.10	0.24	
30-day				pH 6.0-6.9
mean		0.05	0.08	
White sugar factory	(only mixed condensate)	(kg/t raw syrup)		
max.daily value		0.18	0.11	
30-day				pH 6.0-6.9

mean		0.09	0.035	
Liquid sugar factory	(only mixed condensate)	(kg/t raw syrup)		
max.daily value		0.30	0.09	
30-day				pH 6.0 - 6.9
mean		0.15	0.03	

With regard to sugar factories, the noise immission guide values are (in Germany) 60 dB(A) in the daytime and 45 dB(A) at night. Cane sugar factories are generally located in the centre of the growing area, very rarely in the vicinity of sizeable residential areas. The design of factories is light and open (due to the climate); cane is received and conveyed to the mill in the open air (large quantities of dust generated).

Noise emissions can be restricted by structural and acoustic measures, with housings provided around sources of noise and soundproofing.

Where the noise from certain tasks or areas of the factory cannot be restricted or insulated, personnel shall be issued with appropriate individual protective gear.

These include, in particular, tipping and bagging plants, cane handling and roller extraction, washing plants for the raw material and the centrifuge station. In the workshop area, they

include mainly work at rotary machines with a diameter > 500 mm, sheet metal processing machines and drilling and punching machines. The acoustic power level in these areas ranges from between 80 and 130 dB(A). At values of > 85 dB(A), individual protective gear (ear plugs, ear muffs) must be worn. With acoustic pressure levels of > 115 dB(A), the combined use of both items is recommended.

3.2 Technology for the reduction of emissions and emission monitoring

Measures to prevent damage due to atmospheric sulphur dioxide immissions in flue gases comprise the retention of SO_2 in desulphurisation plants (e.g. absorption in lime milk) and the use of low-sulphur fuels. The installation of a scrubber before the chimney inlet has proved successful in reducing the emission load in waste gases. As well as its action on dust, this scrubbing operation achieves an SO_2 separation of some 30%. If sludge from calcium carbonate precipitation is used as the washing liquid, pure gas dust concentrations of less than 75 mg/m^3(f) are obtained. At the same time the SO_2 emission is reduced by 60 to 70 %. "Calcium carbonate precipitation scrubbing" is therefore a particularly good dust and SO_2 separation method as it does not pose any additional wastewater or residue problems.

Dust emissions occurring inside the sugar factory are reduced with scrubbers or fabric filters and the pure gas concentration is less than 20 mg/m^3. Dust levels are kept low in the same way during further processing stages.

In the cane sugar industry, the generally high proportion of flue ash necessitates flue gas purification measures. Older furnace plants can be easily fitted with wet or dry separators (cyclones: approx. 96% effective, more investment- and maintenance-intensive than wet separators). The water requirement figures for wet separation are approx. 0.025 m^3 water/25 m^3 gas.

Emissions and the temperature in the waste gas from steam generation and slice drying are measured and monitored by integrated, continuously operating measuring instruments. In the cane sugar industry, portable, manually operated equipment (e.g. Orsat apparatus) is used mainly to determine, for example, oxygen, carbon dioxide and monoxide. If state-of-the-art waste gas purification systems are installed in new plants, and if dust emissions are below 75 mg/m^3, daily measurements with a portable unit are adequate.

Any odour nuisance due to ammonia emissions is largely suppressed in advance by closed-circuit systems.

In principle lagoons should be fitted with additional aeration equipment, and aeration rollers have proved extremely successful here. They should not be located in the immediate vicinity of a factory or residential area (upwind).

A number of processes can be used to measure rate of discharge, e.g. measurement of flow rate with an impeller device and integration via the discharge cross section, or direct

determination with a measuring weir.

The mixed samples taken for wastewater assessment are analysed for BOD_5 according to DEV (source: (5)) and for sludge deposits, COD and toxicity to fish according to DIN. The EPA has specified the analysis methods for the cane sugar industry in "Methods of Chemical Analysis of Water and Wastes". In the case of lagoons, random samples are adequate in view of the low fluctuations over time of wastewater composition and the long retention times.

Control services and control mechanisms should be put in place to check that environmental provisions are observed, e.g. environmental protection consultants. Their task would also involve checking that environmental protection installations are in good working order and are regularly maintained, and they would also be responsible for personnel training and making personnel aware of environmental issues. Medical care should be provided inside the works and for the local population.

3.3 Limit values issued to protect health

Substances for which maximum workplace concentrations (MAK values) or technical approximate concentrations (TRK) apply in Germany: mg/m^3 Application/source

Ammonia 35 - Raw material treatment, extraction, juice purification, juice concentration, lagoons;

Asbestos dust 0.025 - Heat insulation, filter aids (diatomaceous earth);

Lead 0.1 - Laboratory: lead acetate solution for the clarification of juice samples for polarisation analysis;

Calcium oxide 5 - Milk of lime manufacture: juice purification, juice neutralisation, wastewater treatment; lime burning;

Hydrogen chloride 7 - Evaporator station: cleaning with dilute hydrochloric acid to remove incrustations (calcium carbonate);

Formaldehyde 1.2 - Disinfectants: at places in the production area at risk from microorganisms, mainly extraction;

Hydrazine 0.13 - Anticorrosives for boiler feed water (chemical oxygen bonding with hydrazine hydrate);

Carbon dioxide 9000 - Juice purification (calcium carbonate precipitation); lime burning;

Sulphur dioxide 5 - Made from sulphur in sulphur furnaces, juice purification (calcium sulphite precipitation), acidification of the extraction water, waste gases where fossil fuels are used;

Hydrogen sulphide 15 - Raw material treatment, lagoons;

Dust (generally) 6 - Cane receipt and crushing, slice and sugar drying, sugar bagging; storage of excess bagasse.

Synthetic flocculants do not create dust or irritate the skin when handled, and do not constitute any toxicological hazard. Carcinogenic substances and substances which are suspected of having carcinogenic potential are: asbestos dust, alkali chromates and lead chromate (laboratory reagents), formaldehyde, hydrazine, fumes from VA welding.

The lethal dose (LD_{50}) of a 39% formaldehyde solution is 800 mg/kg body weight (oral: rat); according to the working materials ordinance *Arbeitsstoff-Verordnung* classified as "low toxicity" and labelled with the hazard symbol R22 ("harmful if swallowed!) (necroses of the mouth, oesophagus, stomach).

Measures: in principle toxic chemicals must always to be kept sealed; the wearing of rubber gloves is recommended for analysis work; vessels and instruments must be thoroughly cleaned; installation of effective extraction and ventilation systems.

4. Interaction with other sectors

Sugar is produced jointly by agriculture (crop growing) and industry (processing technology), and there are close links in the ecological and technical fields. The use of modern agricultural knowledge and methods in the growing of the raw material, particularly with regard to fertilizer and pesticide application, largely determines the technological value of beet and cane (all physical, mechanical, chemical and biological properties of the raw material). High-quality raw material facilitates the tasks of extraction and juice purification and this in turn is reflected in improved technological - and hence in the final analysis economic - performance of the factory (higher sugar yields).

Excess bagasse can be used for the additional generation of electricity for the national grid (power stations sector) or for briquette production (domestic fuel supply). Bagasse is also a raw material for the manufacture of hardboard, cardboard or paper (wood and paper sector). Molasses, as well as extracts from cane and beet, are used as the raw material for fermentation processes (fermentation technology and biotechnology sector). Sugar is processed in numerous branches of the food industry. Refined sugar can be used in drug manufacture (pharmaceuticals sector).

All sugar beet and some sugar cane processing factories are equipped with lime kilns for the production of calcium oxide and carbon dioxide, and there are thus parallels with the cement/lime sector.

There are also links with the water supply, wastewater treatment and solid waste disposal

sectors generally.

5. Summary assessment of environmental relevance

The impact on the environment from the sugar extraction process and the processing of the by-products from it are manifold, but can be kept to a reasonable, and in part legally prescribed, minimum level by means of established methods and processes. In new beet sugar factories the proportion of costs required for installations to protect the environment stands at some 15 to 20 % of total investment costs, while the figure for cane sugar factories is 10 to 15 %.

The wastewater produced can be minimised by optimum design of internal water circuits and the use of established purification processes (lagoon degradation/biological treatment plants). The rational control of the process must prevent any sugar solutions entering water circuits. This not only reduces pollution but increases profitability. Dumps for filter residues and earth can be used for soil conditioning once the load has been degraded. The production of fuel in the form of biogas should be taken into account when planning new factories.

Emissions from power stations and drying plants can be contained with the treatment technologies which have now been developed. A large quantity of soot and ash must be

expected in the waste gas, particularly where bagasse is used as fuel, and consequently installations to optimise the combustion process and waste gas purification must be provided.

The open design of factories in warmer climates appears to obstruct possible noise prevention measures, thus noise nuisance would seem to be avoidable only by siting factories at an appropriate distance from residential areas.

In principle the environmental impact caused by sugar factories can be minimised by current technology. In the preparatory phase, it must be ensured that the plant installed will continue to be both fully operational and fully used for many years. This calls for the training of specialists at a technical level who realise the need for regular maintenance work. Training projects for sugar technicians and workmen can be appropriately integrated in sugar factories.

Sugar factories contribute to the general economic development of a country, including the intensification of agriculture, infrastructural improvement, start of the general industrialisation of rural areas and job creation in agriculture and manufacture, all of which attracts the potential workforce in the surrounding area. This generally leads to the uncontrolled growth of local communities and overburdening of the infrastructure and public services. Settlements in the immediate vicinity of the site must therefore be prevented from the outset. To minimise detrimental effects at the earliest possible stage, close

cooperation must be sought at planning stage with the relevant authorities on the regional development plan. Likewise, the affected population groups - and this includes women - should be involved in the decision-making process at all planning phases so as to resolve environmental problems which may arise, e.g. land-use conflicts.

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<u>Appendices:</u>

Appendix 1: Flow chart - raw sugar manufacture from sugar cane

Appendix 2: Flow chart - white sugar manufacture from beet

Appendix 3: Flow chart - refining raw cane sugar

Appendix 4: Water management in a beet sugar factory

Appendix 5: Wastewater control in a cane sugar factory

Flow chart - raw sugar manufacture from sugar cane

Flow chart - white sugar manufacture from sugar beet

Flow chart - refining raw sugar cane

Water management in a beet sugar factory

Wastewater control in a cane sugar factory

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