Integrated environmental protection

With its integrated concept, Badische Stahlwerke can show that environmental protection and high productivity are not contradictory. The basis for success is to adopt a proactive and systematic procedure to deal with all environmental issues that affect an electric steelmaking plant.

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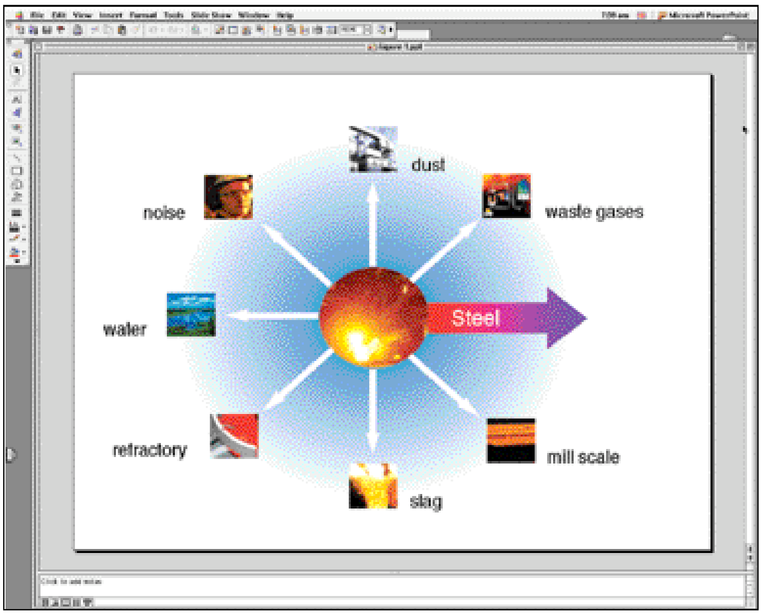
In the past 30 years the environmental consciousness of the European public has grown noticeably. In particular, environmental groups as well as the Green Party have become very popular and as a consequence, many laws and directives have been released by national governments as well as the European Union, which affect the steel industry.

The integrated environmental protection concept

In 1987, the World Commission on Environment and Development – the Brundtland Commission – first defined the idea of sustainable development. The most quoted definition is: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." To achieve this concept it is essential to understand the interconnections between the economy, the environment and the society of an economic area. For a steel mill this means that an environmental protection concept should:

- Show that high productivity and environmental protection are not contradictory (economy)
- Assure legal security concerning the environmental obligations made by law and by the authorities (environment)
- Increase acceptance by the public of a steelmaking company (society)

BSW operates a highly productive steel shop, with more than1.9Mt of billets produced in 2003 via two 90t AC EAFs. The billets are rolled in a wire rod mill and a bar mill. The plant itself is situated close to the recreational area of the Black Forest in south-west Germany on the river Rhine. In addition, as this is not a traditional steelmaking or industrial area, the public and the authorities are very sensitive towards environmental matters. Therefore, over the past ten years BSW has implemented an environmental protection system at a very high cost (€40 million), but also with a lot of advantages regarding cost savings and legal security.



● **Figure 1**
Environmental protection concept at BSW

This environmental protection system consists of both technical and organisational measures to fulfil the above-mentioned demands. These measures apply to all 'steel plant emissions', including off-gases, by-products, water and noise. All these measures are embedded in an environmental management system according to ISO 14001. *Figure 1* shows the environmental protection concept. In the following we will describe how all 'emissions' are dealt with and how the environmental management system supports these measures.

EAF dust

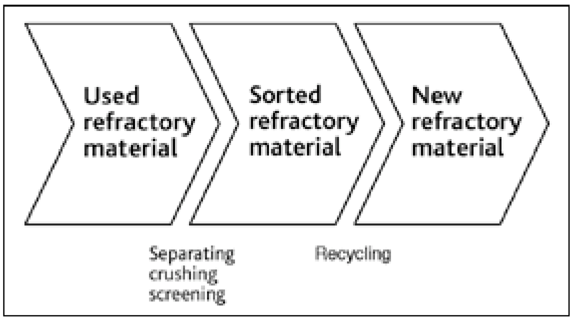
During steelmaking 17–19kg of dust per tonne of steel are generated. Due to the use of shredded scrap, the zinc content in this dust is around 30%, so the dust is treated by contractors in a rotary kiln (WAELZ-process) to recover zinc and lead.

Waste gases

The off-gas system at BSW consists of a post combustion chamber right after the furnace elbow,

	Limiting values			Stack emission 2001	
Parameter	Unit	Stack 1	Stack 2	Stack 1	Stack 2
Dust	mg/Nm³	4	1.5	0.6	0.07
Mercury	mg/Nm³	0.05	0.01	0.027	<0.001
Cadmium	mg/Nm³	0.004	0.004	<0.0004	<0.0007
NO_x	mg/Nm³	25	15	20	4
SO_2	mg/Nm³	-	-	12	1
Dioxin/ Furanng	TE/Nm³	0.1	0.1	0.052	0.031

● **Table 1** ***Limiting values for chimney emissions and emission values at BSW***



● **Figure 2** ***Principle of refractory treatment***

followed by a water spraying chamber to rapidly cool the primary fumes to less than 250°C. After the chamber the gas is mixed with the secondary fumes before they enter the bag houses. This results in very low dioxin and furan emissions. Dust emissions, as well as carbon monoxide and mercury, are continuously measured in the stack and reported directly to the authorities. The yearly average dust concentration is less than 1mg/Nm³, which is far below the limiting value of 4mg/Nm³ for Badische Stahlwerke. These low emission values can be reached with normal, well-maintained filter technology. *Table 1* shows the results of a measurement campaign at the two stacks in 2001.

Refractory material

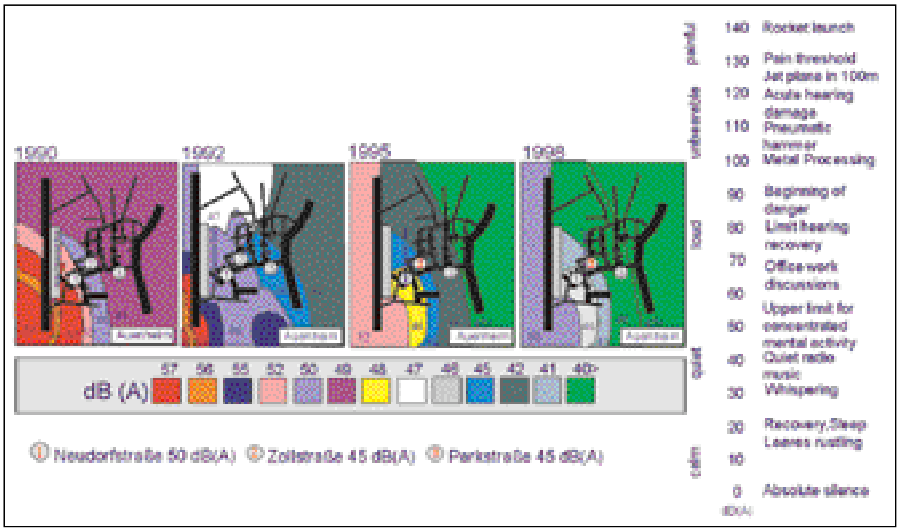
BSW, like other steel plants, uses several different kinds of refractory material depending on application. All material is collected separately and sold back to the suppliers after treatment. The treatment process is mainly about iron separation and screening to the desired grain sizes for the customer. *Figure 2* shows the principle of refractory treatment.

Noise emissions

BSW is situated on a narrow peninsula between the river Kinzig and the port basin of the river Rhine; the village of Auenheim is only 300m away from the melt shop and scrap yard. As a consequence, following the first noise measurements carried out in the vicinity of BSW in 1976, a 600m long by 10m high noise protection wall parallel to the steel mill and the village was built and vegetation was planted. In 1987, changes in production and stricter environmental legislation caused BSW to develop an overall noise reduction concept, together with a leading technical institute. The main measures for noise reduction were the construction of:

- Noise protection walls at the scrap yard and billet yard
- Noise insulation walls at steel mill and rolling mill buildings

Together with a large number of minor steps, these measures have led to the desired results. For example, the noise level of the scrap yard is measured continuously at the house adjoining the plant. When there is a noise peak from scrap loading over a certain limit, a signal in the crane cabin indicates a violation of the limiting value to the crane driver. The sound level at this measuring point on the roof of the house in Auenheim was reduced from 50dB(A) in 1990 to 45dB(A) in 1998. *Figure 3* shows the development of noise reduction at BSW since 1990.



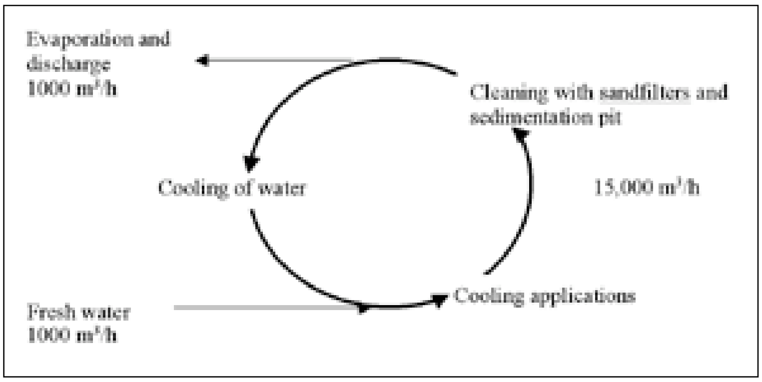
● **Figure 3** ***Development of noise reduction***

Water emissions

The main issues of BSW's water treatment are the decrease of specific water consumption and discharge of clean water, not zero discharge. BSW has five ground water wells on site and discharges the cleaned water into

Parameter	Unit	Limit	BSW
Chemical oxygen demand (COD)	mg/l	12.0	< 5.0
Phosphorus (P)	mg/l	0.1	0.020
Nitrogen (N)	mg/l	5.0	1.98
Adsorbable organically bound halogens (AOX)	mg/l	0.1	< 0.01
Mercury (Hg)	mg/l	0.001	< 0.0005
Cadmium (Cd)	mg/l	0.005	< 0.0005
Chromium (Cr)	mg/l	0.05	< 0.002
Nickel (Ni)	mg/l	0.05	0.017
Lead (Pb)	mg/l	0.05	< 0.002
Copper (Cu)	mg/l	0.05	0.017

● **Table 2** ***Average waste water analysis***



● **Figure 4** ***Principle of water treatment***

● **Figure 5** ***Motorway in southwest Germany made of BSW slag***

● **Figure 6** ***Bank reinforcement at the river Rhine***

the river Rhine. The only impurity is mill scale from the continuous casting machines and the rolling mills. This is extracted by a combination of sedimentation pit and sand filters. The BSW laboratory analyses the waste water once a month and the content of mill scale is checked every day. *Table 2* shows the average BSW waste water analysis.

Figure 4 shows the principle of water treatment at BSW and the water amounts needed. After cleaning, the water is cooled in cooling towers and resupplied to the plant applications. This circulation of the cooling water is the reason for the decrease in specific water consumption from around 20m^3/t at the beginning of the 1990s down to 6m^3/t of steel today.

EAF slag

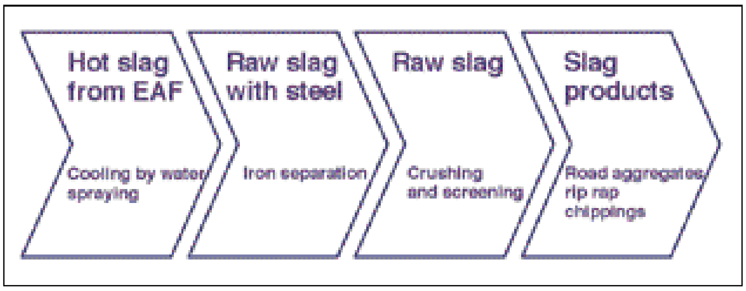
In 2003, about 130kg of EAF slag per tonne of steel was produced, a total of 250,000t of slag, including separation iron. A further 25,000t of slag was produced in the two ladle furnaces. EAF slag is rich in FeOx and is therefore of a dark, almost black colour.

The lime content is fairly high at 28.5%, but mainly bound to iron and silicon. As a consequence the percentage of free lime is low, typically <1%. This is one of the major requirements for the use of slag as a building material in road construction. Free lime and magnesium oxides in the slag are the reason for the increase in volume when treated with water (weathering). Chromium mainly occurs in BSW slag, bound in a spinel-type compound, which is insoluble in water. This means that only negligible amounts of chromium can be leached out by water. This makes EAF slag a suitable material for many applications without environmental harm.

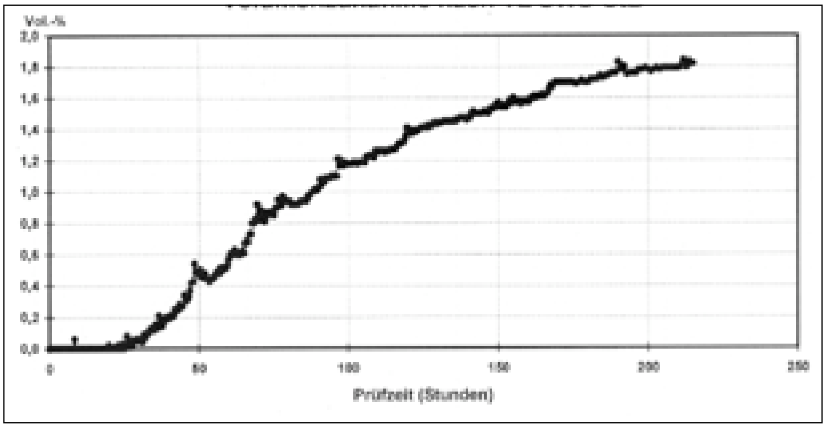
● **Figure 7** ***Cartway in Black Forrest made of EAF and LF slag***

Parameter	Unit	Limit value	Average value 2002
pH value		12.5	11.3
Conductivity	mS/m	100.0	62.2
Arsenic (As)	mg/l	0.1	0.026
Chromium (Cr)	mg/l	0.05	0.017
Mercury (Hg)	mg/l	0.001	< 0.0001
Cadmium (Cd)	mg/l	0.005	< 0.0005
Zinc (Zn)	mg/l	0.5	0.012

● **Table 3** ***Leaching of BSW EAF slag – analysis of leachate***



● **Figure 8** ***Principle of slag treatment process at Badische Stahlwerke***



● **Figure 9** ***Typical volume increase curve of EAF slag with the volume stability test***

The main arguments for using slag as a building material are the physical properties such as hardness and specific weight. Ladle furnace slag is high in lime and low in iron, hence the physical properties are different from those of EAF slag. The volume stability is not as good and it often breaks down to sand while cooling, so other applications have to be found for the use of this material.

Since 1992, BSW has treated its slag prior to sale to building contractors for various uses. EAF slag is used mainly for road construction in the sub-base and in the asphalt layer. *Figure 5* shows a German motorway made of BSW slag. Due to its high specific weight EAF slag can also be used as armour stones for bank reinforcement. *Figure 6* shows an example at the river Rhine. Ladle furnace slag can be used to build cart ways in forests as shown in *Figure 7*.

The slag treatment process consists of four steps: treatment in the furnace, cooling with water, iron separation, and crushing and screening. The process is shown schematically in *Figure 8*.

As with any other product, treated EAF slag needs continuous quality control, both for better process control and for customer assurance. EAF slag has to pass all the technical tests that are required for natural building materials, one of which is the volume stability test to prove weather resistance, and therefore usability, of the material itself. A sample of slag is treated with steam for 7 days, and the increase in volume is measured continuously and should not exceed 5 volume %. The result of such a test is shown in *Figure 9*.

There are also many tests to evaluate the environmental impact of slag used as a building material, however they all determine the propensity for the leaching of metals from slag with water. The most common test in Germany is the DEV S4 where 200g of slag with a special grain size distribution is leached with 2 litres of water for 24 hours. After filtration the leachate is analysed. *Table 3* shows a typical analysis of the leachate of BSW slag with the limiting values according to German law.

These results show that BSW slag can comply with all the environmental restrictions that enable slag to be used in many applications.

Mill scale

Mill scale is generated mainly at continuous casting machines and rolling mills. The iron content can reach 70%, mostly as iron oxide, so industries that need raw materials with high iron content are possible customers for this material. BSW delivers its mill scale to blast furnaces, cement plants and brickworks but before usage in blast furnaces mill scale is added to the mix at the sinter plant. The complete output of mill scale at BSW is recycled by one or other of these methods.

Environmental management system

In 1997, Badische Stahlwerke became the first plant in Europe to implement an environmental management system (EMS) on a voluntary basis. BSW was certified in 1997 according to the European standard EMAS (Environmental management audit scheme). In 2000, the company implemented a system according to ISO 14001. Although there are disadvantages with such a system the advantages are predominant and its use contributes towards BSW's ongoing environmental performance.

Steel production

As well as all the effort that has gone into environmental improvement, the productivity of the meltshop and two rolling mills has been increased, from 0.97Mt in 1988 to more than 1.9Mt of prime billets in 2003. Thus, highly productive steel plants can also show excellent environmental performance (see *Figure 10*).

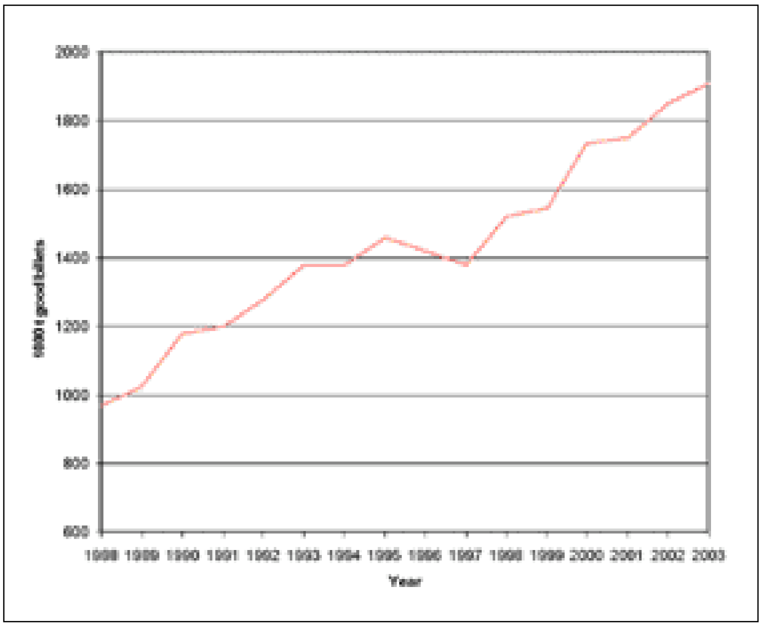
Environmental costs

The costs for the dedusting plant, water cleaning, recycling of products equate to more than €7 per tonne of steel. This figure does not include investment costs for new environmental protection measures.

Summary

After more than ten years of intense work in the field of environmental protection, the following advantages from the integrated concept of BSW have been achieved:

- Reduced disposal costs for by-products
- High productivity and environmental protection are not contradictory



● **Figure 10** ***Productivity of Badische Stahlwerke from 1988 to 2003***

- Legal security
- High acceptance by public and employees

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