worldsteel ASSOCIATION

WATER MANAGEMENT IN THE STEEL INDUSTRY

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Director General
World Steel Association (worldsteel)

Rue Colonel Bourg 120
B-1140 Brussels, Belgium
Tel: +32 (0)2 702 89 00
Fax: +32 (0)2 702 88 99

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Foreword from the Project Chairman

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Steelworks are located in many regions of the world and the issues regarding water management are equally diverse. In some cases availability of water is the main concern. In others it is the quality of water and the release of it back into natural water systems.

Water management plays a critical role in the viability of steel plants, especially in regions of water scarcity. Growing demand for water will make continuous recycling a business imperative in the steel industry.

The worldsteel water management project was started in September 2007 with broad representation from worldsteel members. There were meetings in Brussels, IJmuiden (the Netherlands) and Vitoria (Brazil). However, the global financial crisis that began in 2008 had a huge impact on our industry. For this project, travel restrictions meant that meetings had to be cancelled. Only one more meeting was held, in March in 2010 in Belgium.

In the early days of the project we decided to develop a web-based survey to make the participation threshold as low as possible and to generate standardised simple data sets. Although a lot of work was put into this endeavour the survey was unsuccessful and, unfortunately, valuable input was lost.

In spite of these setbacks we learned a lot and managed in May 2010 to re-launch the survey, this time based on existing software tools. This new effort was very successful and worldsteel members generated 29 valuable datasets on water management in all possible steelmaking process steps. The data allowed us to analyse water management in the global steel industry and to draw some general conclusions on water use and treatment techniques.

The job is not yet finished. To make this work really worthwhile, to have in-depth analysis and find the real best practises of water management in the industry we recommend that as many worldsteel members as possible should continue to monitor there water management performance with the tools provided in this study.

This project would not have been possible without a group of very dedicated people and their companies. It is my experience that this kind of dedication – and the support of worldsteel staff – are absolutely necessary to bring these kinds of projects to success.

I would like to thank all participants for their input and in particular those who hosted meetings and showed us their water management practices.

Hans Regtuit
General Manager, Environmental Management, Tata Steel

Foreword from the Secretary of the Technology and Environment Committee

This project work was started by the Committee on Environmental Affairs (ENCO) under the chairmanship of Hidenori Yasuoka, JFE Steel, continued under James Volanski and Fred Harnack, U.S. Steel, and completed in 2010 by the Technology and Environment Committee (TECO) under chairman Pierre Gugliermina, ArcelorMittal. The project spanned three years, including a period of economic crisis which was one of the most difficult times the steel industry has seen.

This report identifies the challenges for the steel industry to reach the most efficient use of water. It reflects the current state of good practices and water intensity. This is the first study on water use undertaken on its own. As freshwater becomes a more scarce resource and regulatory requirements increase on its use, returned quality and temperature, the work is likely to be repeated in the near future.

The report covers a wide range of operating conditions. Many organisations have sufficient access to water for all the cooling or processing needs and have little incentive to reduce their consumption. Others need to generate and conserve every drop of their water supply. The ingenuity by which the water is extracted, used, reused, recycled, treated and reintroduced into the environment is inspiring.

Knowledge gained from the work in this report is transferable to other steelmaking sites. Water is a generic coolant for many applications and the techniques in use at steel plants are transferable to other industries as well.

The report also identifies the high level of technical and management skills within the steel industry. Achievements in water usage can be, in some cases, a benchmark for others. Techniques to make the most efficient use of water will be a challenge for the rest of the industry to follow. The steel industry is aware of its responsibilities in managing resources and this report demonstrates that it can reach a sustainable operation.

worldsteel is grateful to project Chairman Hans Regtuit from Tata Steel IJmuiden (formerly Corus IJmuiden) and his team members Antoine van Hoorn and Miklos Szabo. Project leader Åsa Ekdahl, worldsteel's Technology and Environment Manager, delivered the seminar to TECO and completed this report over the past year.

worldsteel recommends that this work be repeated in the near future to ensure that water as a topic and resource is maintained at the forefront of technology in the future.

Henk Reimink
General Manager, Safety, Technology and Environment, worldsteel

Executive summary

As part of a worldsteel water management survey, data was received from 29 steelworks, representing 8% or ~111 million tonnes of the global steel output in 2008. This report presents the results from the survey which included all steelmaking activities and covered both water quality and quantity issues. It provides specific information about the (sub-)processes, the water intake, the types of water used, reused and discharged. It also deals with good pre- and post-treatment techniques and water management issues. All the information is available from a digital database that can be used to optimise processes and for other purposes.

The report covers:

- general information on freshwater availability and water management in the steel industry
- the goal, scope and methodology of the data collection
- results and good water management practises.

The configuration of a steel plant, its geographical situation and local legislation determine in what way, how much and what type of water is used and discharged. Therefore, the data presented in this report cannot be generalised. Instead, it presents a picture of the current situation, which more often than not highlights the differences among plants. In spite of the diversity, many practices described in the report can be a starting point for improved water management because they can be adapted to the specific conditions of an individual site.

The results of the collected data can also be used to compare sites with similar configurations and act as a trigger for improvement projects and even cooperation between sites, or benchmarking.

This report makes a distinction between the two main steel production routes; the integrated route and the electric arc furnace (EAF) route. For the integrated route, 17 plants contributed data. For these plants the average consumption and discharge are 28.6m^3/tonne of steel and 25.3m^3/tonne of steel respectively. Eight survey participants produce steel via the EAF route and their average consumption and discharge are 28.1m^3/tonne of steel and 26.5m^3/tonne of steel respectively.

Water consumption and discharge per tonne of steel are close to each other and few losses seem to occur in the processes, indicating overall efficient use of water. In most cases the loss will be caused by evaporation.

Blast furnace processes are the most significant water consumers, followed in order by hot rolling, cold rolling and cokemaking. In assessing the numbers for these processes, it is important to note that water usage is expressed in m^3/tonne of the specific product and not in m^3/tonne of steel.

Significant differences can be observed between plants using once-through cooling and those using circulation cooling. Nearly 81% of the water used goes to once-through cooling. Seawater is commonly used for once-through cooling, especially at integrated steelworks.

The assumption that good water management is expressed by the least water used per unit of production is flawed because it does not tell the whole story. The amount, variety and quality of the available water must also be taken into account.

Steel plants and companies can use the water management tool developed for the project to assess the quality of their water management. The tool covers nine areas including: policy, water management and organisation, and water metering. Respondents rate their water management efforts on a scale of 0 to 4.

For this survey, responding steel plants rated their water management efforts an average 67% across the matrix; 31% being the lowest score and 94% the highest plant-specific score. The steelworks rated their water management efforts rather high. This could be an indication that the participating companies are more active in water management than non-participants. The results, therefore, might not reflect the efforts of the entire steel industry.

An overview of good practices on water management for every process step is presented through case studies. The case studies, contributed by the participants, help to share experience and provide solutions. They also show how water availability, type of water and legislation determine what pre- and post treatment techniques are applied. Consequently, conclusions about the best or better techniques cannot be easily made.

The benefits of this project for the global steel industry can be enhanced if the cooperation established during the project is continued, for example through faster implementation of proven good practices and/or a solid network for problem-solving. As stated above, the survey tool is a useful and simple way to assess water management within a plant or process.

The most important recommendation from the report is to create a network of water management experts who can be used for communications on water issues and to organise workshops to exchange information and knowledge. To support this work, data should be collected every two years, using the water survey developed for this project.

About this report

This report is the result of the work of the worldsteel water management working group. It was made possible by the participation of experts from steel companies around the world.

The first chapter gives the project timeline and composition of the working group. The second chapter covers the background of the steel industry's water issues and technical challenges. The third chapter describes the aim and objectives of the working group.

The following chapters explore the worldsteel water survey: the methodology, survey results, project conclusions and recommendations.

Appendix A contains identified good practices presented as case studies. These were provided by members of the working group. The diagrams that show the results for each process step are available on the CD that accompanies this report.

The water management tool is also provided on the accompanying CD. The application, developed in Microsoft Excel, gives access to additional information about water use in the steel industry.

The following information is on the CD:

- a user guide
- information and graphs on how water is used in a plant
- information and graphs on how water is used in a given process and sub-process
- comprehensive flowcharts on water consumption of a particular plant
- a list of participants
- the treatment techniques used (pre- and post-treatment)
- information on effluent quality
- an intake poster.

All the data on the CD comes from participating companies and has been processed to be comparable.

This report was written by people who were closely associated with the development of the survey and the analyses of the results. The drafting team consisted of three consultants from Corus Steel (now Tata Steel IJmuiden) in the Netherlands, one consultant from Corus Steel (now Tata Steel Europe) in the UK and the project manager from worldsteel.

Parallel to the writing of this report, the group contributed an article to the German journal 'Stahl und Eisen'. The paper was published in a special English edition of issue 11/2010: '150 years of VDEh'. The article is a summary of the worldsteel water management study.

About worldsteel

The World Steel Association (worldsteel) is one of the largest and most dynamic industry associations in the world. worldsteel represents approximately 170 steel producers (including 19 of the world's 20 largest steel companies), national and regional steel industry associations, and steel research institutes. worldsteel members produce around 85% of the world's steel.

The association provides a forum for the world steel industry to address the major strategic issues and challenges it faces on a global basis. In addition, worldsteel facilitates the benchmarking of best practices amongst its members, across many aspects of steel manufacturing.

The association promotes steel as a product and the steel industry to customers, industry, media bodies, and the general public. It assists its members to develop the market for steel. worldsteel promotes a zero-harm working environment for steel industry employees and contractors.

worldsteel was founded in 1967. It is a non-profit organisation with headquarters in Brussels, Belgium. In 2006, worldsteel opened a second office in Beijing, China.

Introduction

In the 2005 worldsteel sustainability report, member companies identified water as the most important issue after climate change and air quality for a sustainable steel industry. This lead to a proposal for a new working group on water management in 2006. Its goal was to provide a reference document for sustainable water management in the steel industry.

The working group included all steelmaking activities (site infrastructures) and covered water quality and quantity issues. The approach has been similar to that of other worldsteel projects; put experts working in the same sector into contact, organise expert discussions, develop surveys, and look for worldwide member representation and comparable configurations.

The working group investigated how different steel plants, from all over the world, manage their water usage. Twenty-nine plants with different configurations, ranging from separate hot rolling mills to fully integrated plants, participated and gave detailed information on their water management practices.

The compiled information gives an overview of the key water issues in the steel industry. How water is used is important from an environmental point of view as well as from a technical and economic point of view. The project did not focus on the use of freshwater only, but on all types of water used (including salt and brackish water). As such, this report provides a good starting point for the exploration of water management in the steel industry and proves that steel producers can learn a lot from each other.

Project timeline and meetings

The working group met four times. More meetings were planned but the difficult economic conditions at the end of 2008 and 2009 did not allow for them to take place.

Meeting	Date	Location	Host
1	June 2007	Brussels, Belgium	worldsteel
2	October 2007	IJmuiden, The Netherlands	Corus
3	March 2008	Vitória, Brazil	ArcelorMittal Tubarão
4	March 2010	Brussels and Ghent, Belgium	worldsteel and ArcelorMittal Ghent

Table 1: Meeting dates and hosts

Working group

The project group was made up of the following companies and associations (those in bold participated in the re-launch of the survey):

ArcelorMittal	**HKM**	Ternium
Baosteel	**Isdemir**	**Třinecké železárny**
China Steel	**POSCO**	Usiminas
CMC	**Rautaruukki**	U. S. Steel Corporation
Corus*	Sail	VDEh
Duferco	**Salzgitter**	voestalpine
Essar	**Tata Steel**	
Hadeed (part of SABIC)	**Tenaris**	

*Tata acquired Corus during the project. The name Corus Staal BV was changed to Tata Steel IJmuiden BV and Corus Steel became Tata Steel Europe on 27 September 2010.

Figure 1: Geographic distribution of the project team and meeting locations

Background

"Water, water everywhere, Nor any drop to drink" (Coleridge, 1798). This is the reality facing many around the world as water resources of already vulnerable ecosystems are not sustainably managed.

Worldwide freshwater availability and use

About 70% of the Earth's surface is covered by water. Although water is seemingly abundant, freshwater is not. Only 3% of the world's water is freshwater and 2% of that in glaciers. Only 1% or 12 million km^3 of freshwater is accessible to people in liquid form (Pearce, 2007).

Out of this already small amount of available freshwater, 70% is withdrawn for irrigation in agriculture (Chapagain, 2004) and 22% used by industry (Unesco website). It has been predicted that water could become a commodity to rival oil in the 21st century.

In the early part of June 2008, a panel of leading global experts convened by Goldman Sachs in London to confront the "top five risks" to global prosperity sounded the alert that catastrophic water shortages could prove an even bigger danger to the human race than depletion of energy supply and deficient food supplies. A Goldman Sachs report notes that the demand for freshwater is doubling every 20 years and calls it "the petroleum for the next century".

According to Jean-Claude Trichet, the President of the European Central Bank (ECB), "from a world of seemingly unlimited resources, mankind is gradually accustoming itself to the Earth as a limited, crowded and finite space, with limited resources for extraction and a narrowing capacity for water disposal or pollution" (Duncan, 2008).

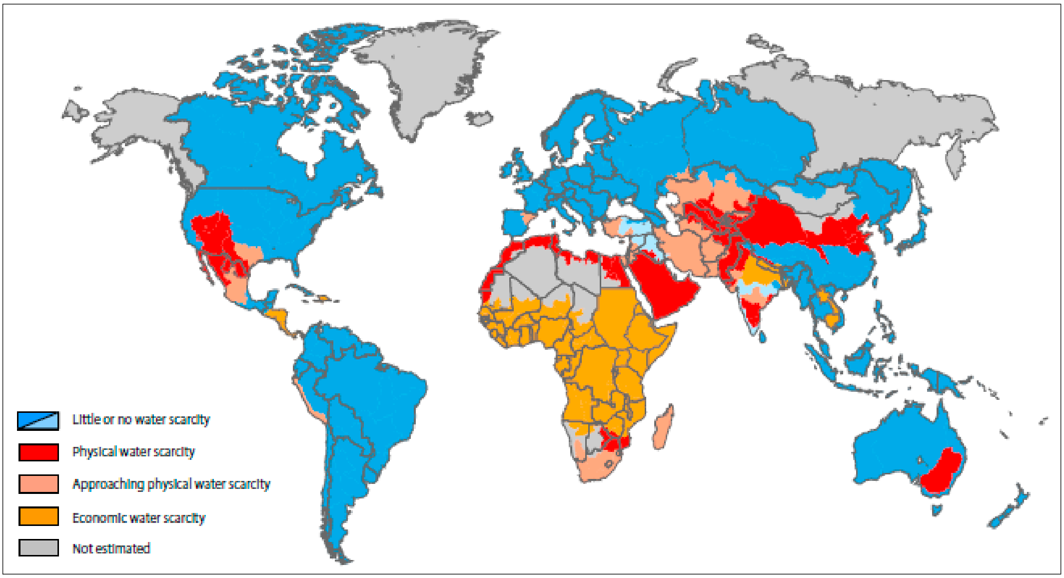
Indeed, the social, economic, and environmental impacts of past water resources development and looming prospects of worldwide freshwater scarcity are driving the shift to a new paradigm in water resources management within companies (Takashi, 2007).

Regional freshwater availability

As shown in Figure 2 below, a quarter of the world's population lives in areas characterised by physical water scarcity. The problem is worst in Africa, parts of the Middle-East and Asia and in areas of Australia and the Americas. Other areas with worsening prospects are the Middle-East and Asia.

Northern Europe is the region least affected by water shortage. Due to its abundance, water in this region has long been overlooked as a resource, but even here recent changes in legislation and water policies have brought water to the top of the agenda for governments and organisations.

Climate change is further threatening water availability in areas already affected by scarcity. To achieve more sustainable access to freshwater worldwide, great contributions are required from all parties, especially from water-intense industries.



Red: Physical Water Scarcity. More than 75% of the river flows are allocated to agriculture, industries or domestic purposes (accounting for recycling of return flows). This definition of scarcity—relating water availability to water demand—implies that dry areas are not necessarily water-scarce. For example, Mauritania is dry but not physically water-scarce because demand is low.

Light Red: More than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.

Orange: Economic Water Scarcity. Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists. These areas could benefit by development of additional blue and green water, but human and financial capacity are limiting.

Blue: Abundant water resources relative to use: less than 25% of water from rivers is withdrawn for human purposes.

Figure 2: Areas of physical and economic water scarcity (IWMI, 2006)

Sustainable water management

To guarantee water for domestic as well as industrial use, in particular for water-intensive industries such as steelmaking, water has to be well managed.

The idea of sustainability in the context of meeting human needs while preserving the environment was popularised by the UN's Bruntland report in 1987, which defined sustainable activities as ones where the needs of the present generation are met without compromising the needs of the future generations.

The 1992 UN Earth Summit in Rio de Janeiro addressed global environmental issues and recommended solutions. Two important results of this conference were Agenda 21, which is a comprehensive set of guidelines for achieving sustainability and ISO 14000, which is a group of standards, including ISO 14001, on environmental management and pollution prevention.

Agenda 21 was adopted by 172 nations at the conference and ISO 14001 helps companies to embark on a journey of strategic sustainable development (TRS, 2005).

In recent years, there has been a shift from the traditional 'top-down' approach to a more open management system where all levels concerned have a say in the allocation and use of a resource. When carried out properly, this management system ensures that the needs and concerns of those affected by the use of the resource are addressed, without losing sight of the wider issues touching society as a whole (Devalt website).

Sustainable water management (SWM) can be defined as development and use of water resources in a manner that can be maintained over an indefinite time without causing unacceptable environmental, economic or social consequences (Arnold et al., 2009). SWM involves a whole new way of looking at how we use water resources. The International Hydrological Programme, a UNESCO initiative, noted:

"It is recognised that water problems cannot be solved by quick technical solutions, solutions to water problems require the consideration of cultural, educational, communication and scientific aspects. Given the increasing political recognition of the importance of water, it is in the area of sustainable freshwater management that a major contribution to avoid/solve water-related problems, including future conflicts, can be found."

The problems in water supply are often the consequence of population growth that puts pressure on the hydrological cycle without regard for long-term water availability (Arnold et al., 2009). The purpose of SWM is to deal with water in a holistic manner, taking into account the various sectors affecting water use, including political, economic, social, technological and environmental factors (Dainet website).

Since the Mar del Plata Water Conference hosted by the UN in 1977, SWM has been high on the international agenda. The current understanding of SWM is based primarily upon the principles devised in Dublin during the International Conference on Water and the Environment (ICWE) in 1992, namely:

1. Freshwater is a finite and valuable resource that is essential to sustain life, the environment and development and it should be managed in an integrated manner.
2. The development and management of our water resources should be based on a participatory approach, involving users, planners and policy makers at all levels.
3. Women play a central role in the provision, management and safeguarding of water as a resource.

Water has an economic value and should therefore be recognised as an economic good, taking into account affordability and equity criteria.

Water issues in the steel industry

For the purposes of this report, steel production is classified into three production routes:

- Integrated plants use iron produced from newly-mined materials; iron ore, coal and limestone. The coal is turned into coke in a coke oven plant. The iron ore is made into agglomerates such as sinter and/or pellets. A blast furnace is charged with the coke and agglomerates to produce pig iron. This pig iron is turned into steel in a basic oxygen furnace (BOF). Scrap is used as a cooling agent during this conversion process.
- In the electric arc furnace (EAF) route, steel scrap is melted to produce liquid steel. The combination of an EAF and a hot rolling mill is also known as a mini mill.
- The distinctive feature of the Corex process is that it uses conventional coal instead of coking coal. The Corex process, therefore, does not require a coking plant.

All steelmaking processes, especially in the integrated route, use large amounts of water. However, because the processes are fundamentally different, their material, energy and water needs cannot be usefully compared.

Steel is further processed in a hot-rolling mill. Hot-rolled material can be further processed in finishing mills, which use intermediate steel products to make products for specific end uses.

Water uses at steel plants

Water is an essential resource for the production of crude steel, although usage patterns vary considerably from one plant to another. The steel industry uses salt, brackish and freshwater. Salt water is most commonly used. However, most of it goes to once-through cooling. In much smaller volumes, it is found throughout the steelmaking process, primarily for cooling or heat transfer of heat processing equipment.

Primary iron- and steelmaking processes require raw materials to be heated beyond the melting point of iron, while hot-rolling operations require the materials to be heated to enable certain metallurgical reactions. Heat processing equipment is protected by a combination of refractory linings and water-cooling of the refractory and shell of the equipment.

Water is also used:

- for material conditioning, for example dust control in sinter feeds, slurrying or quenching dust and slag in blast furnaces, mill scale removal in hot- rolling operations, solvent for acid in pickling operations, or rinsing in other rolling operations.
- to control air pollution in primary operations, particularly in integrated mills. One example is wet scrubbers for air pollution abatement.
- for acid control in pickling operations and for wet scrubbers in coating operations that have caustic washing operations. (Johnson, 2003)

In most cases, the water in these processes is cooled and treated, either for reuse at the plant or for return to its original source.

When a large amount of water is applied, a large amount of effluent water is produced. Due to increasing water scarcity and the evolution of water-related legislation, it is crucial to manage the treatment and disposal of this wastewater properly. One of the actions steelworks take to manage wastewater is to monitor the quality and quantity of their emissions to ensure that compliance limits are not exceeded and to enable corrective actions if necessary.

Sustainable water management (SWM) at steel plants

Steelworks are located in vitually all regions of the world. In some places the availability of water is a problem, while in other places the quality of water released back into natural water systems is the main issue. The steel industry tries to meets these challenges by providing solutions. Sometimes the quantity and quality of the locally available freshwater is improved.

Where freshwater is limited, SWM efforts have made it possible to maintain freshwater intake at a relatively low level. Some facilities achieve a freshwater recirculation rate of nearly 100%, creating a ‘zero-effluent' site. SWM plays a critical role in the viability of steel plants, especially in regions of water scarcity. Growing demand for water resources will make continued recycling of water a business imperative in the steel industry (Johnson, 2003).

Technical challenges

Steelworks have evolved, as have their water and effluent networks. Changes over time have often lead to complex pipe networks, and pre-treatment and effluent treatment systems. Quality testing to ensure legal compliance has also become complicated.

Sometimes there is no clear and detailed picture of the types or volumes of water in every part of the system. The starting point of any water and effluent system management should therefore be a pipe inventory and the installation of a comprehensive metering, monitoring and targeting system. This will help to manage the effluent and water systems properly and can even reduce water consumption and effluent discharge considerably.

Steel plants face several technical challenges in improving their environmental performance. Two major issues are high chloride levels in the cooling water and issues arising from efficient final effluent treatment, as explained below.

Cooling water

As mentioned earlier, cooling heat transfer equipment is the main use for water in the steel industry. Cooling towers can reduce the amount of water used. Usage can be minimised by using closed-loop cooling systems (Johnson, 2003).

Unfortunately, without suitable treatment, chloride levels in the cooling water can cause a problem because most corrosion inhibitors are sensitive to chloride concentrations in the water (Abdel-Wahab and Batchelor, 2002). Common cooling system alloys that are susceptible to chlorides include austenitic stainless steels (300 series). Chloride is the main contributor to corrosion of stainless steels, due to high chloride levels in the makeup water and/or high cycles of concentration.

The most likely places for chloride-derived corrosion are crevices or areas where the flow of water is restricted, due to the build-up of corrodent concentrations. Chloride can be found in concentrations from 100 ppm in the bulk water to as high as 10,000 ppm (1%) in a crevice (GE website).

Efficient final effluent treatment

Another major technical challenge faced by the steel industry is the choice of final effluent treatment. In many cases a basic chemical sediment/clarification system combined with flocculant treatment can achieve a water quality that meets legislative effluent discharge targets. However, a sludge by-product of this type of treatment is voluminous and has a density of ~1%w/v that settles slowly and can be difficult to handle. This leads to the need for additional sludge handling by either filter-pressing or centrifuges, and increased landfilling costs. The sludge problem can be overcome by using sludge-reducing techniques, such as the high density sludge (HDS) process.

One technology which has become more common in recent years is the use of membrane processes. Membrane technologies come in various formats, including ultrafiltration (UF), reverse osmosis (RO), electrodialysis (ED) and electrodialysis reversal (EDR). Membranes can provide solutions to practically all water treatment problems. However, they cannot be used as a stand-alone solution because the effluent water entering any membrane process treatment has to be relatively free of colloidal particulates such as silt, iron and manganese oxides (GE website). Unfortunately, combined treatment for large volumes of final effluent is not always cost-effective.

Goal and scope

Goal

The water management group was formed to prepare the steel industry for participation in the global discussion on water. The establishment of key performance indicators (KPIs) was a key goal. Other goals included demonstrating that the sustainability of the steel industry is not compromised by its approach to water, and providing a best practice exchange on water management.

Objectives

The objectives of the project were to achieve efficient water management now and for the future by:

- comparing members' policies and strategies
- benchmarking global rates of water use
- evaluating further opportunities for water use and consumption rate improvements by making an inventory of technologies applied.

Scope

The project focused on all steelmaking activities (site infrastructure), from fully integrated sites to separate rolling mills. It assesed both water quality and quantity issues.

In the beginning, a pre-survey questionnaire was sent to the member companies to identify the most important water-related issues faced by the steel industry. Forty-eight member companies answered the questionnaire. The main water-related issues, in order of importance, were:

1. Quality of wastewater
2. Water recycling and minimisation of consumption
3. Pollutants in the water
4. Implementation of new water management technologies
5. Cost-effectiveness of wastewater treatment technologies
6. Quality of process water
7. Reduction in freshwater consumption
8. Wastewater treatment technologies
9. Threat of shortage in water resources in future
10. Change in approach to water strategy and policy.

The above issues were broken down into KPIs, which were then used to build the survey for data collection. During the meetings it was decided that in addition to the gathering of quantitative data, a section measuring the management philosophies should be added.

A water management performance matrix was therefore included in the survey. It measured on a quantitative format scale softer water management issues such as level of water metering and targeting, the presence/absence of a water manager, organisation and so on.

Uncertainties

The reliability of survey results depends on the robustness of the data. This means that in making comparisons, it is necessary to take into account the quality, accuracy and origin of the data in a way that will not lead to misinterpretation, wrong conclusions or unjustified generalisations.

The working group of the worldsteel water management project was well aware that it is difficult to compare the use of water in different steel plants. When applying the results of the survey the differences must be kept in mind and the report is to be used with caution. Nevertheless, this report provides a good overview and presents a database for water management in the industry.

The uncertainties are, in particular:

- Lack of (exact) monitoring data. The participants completed the questionnaires with existing information. In many cases estimates were made due to a lack of flow measurements. Data was not supplied for some questions.
- Interpretation of the survey. The survey was distributed with default value ranges. More then 90% of all the data could be submitted in this way. For less predictable entries, for example in sub-processes, the survey provided no default ranges. Therefore, these data are particularily difficult to compare.
- Mistakes in submitted data. In some cases questions could have been misinterpreted. Verification was carried out but there is always a margin of error.
- The process configurations of steel companies vary widely. Only data from similar processes can be compared. In some cases the main processes are interlinked and cannot be seen separately.
- The level of detail varies significantly across participants. Sometimes only totals were provided.
- Some participants had difficulties completing the data for reuse flows.
- Some participants included storm water, some did not. In some cases this is this is not clear. The same goes for municipal water.
- Where treatment plants were used for different flows it is difficult to compare a certain flow from a certain process in one plant with that of another plant at the level of sub-processes.

Deliverables

The project outcome is this final report with key performance results per process. The report also provides an overview of technologies and practices used within the industry to manage water.

In addition to the report there is a CD with the water management tool. It offers access to more detailed information about the results and is also useful to develop water management practices in steel companies.

Methodology

Development of the survey and data collection

The first phase of the project concentrated on the type and quality of data that needed to be collected in order for the results to be comparable.

Due to lack of commercially available software able to collect and process vast amounts of complex information, a lot of effort was put into the design and development of a tailor-made survey. A first attempt to collect data was carried out. Unfortunately, the survey proved to be user-unfriendly and data became unusable. Important lessons were learned from this exercise. The project team decided to develop a more user-friendly survey in Microsoft Excel, an existing and flexible program used worldwide. The survey was developed by the Environmental Management Department of Corus Steel (now Tata Steel IJmuiden) in the Netherlands.

Water usage and water discharge in the steel industry are influenced by many factors, not least the site configuration of the plant. The water use of a steel plant depends on local legislation, geography, the economic situation, the kind of water available and, in many cases, a unique combination of (sub-)processes. It was a challenge to use a single survey format to collect data from different types of plants.

The survey was developed in such a way that all identified processes, sub-processes, water varieties, inflows, reuse flows and so on have their own section. Whenever possible, a default range has been included. Not everything can be predicted, however, especially in water management. Therefore, the survey allows data outside of the specified range, in particular in cases where no default values were suggested. A manual with examples was provided.

The following data are covered by the survey:

1. General information about the plant

- name, address, etc.
- annual production of crude steel
- annual intake and discharge numbers (specified for each type of water).

2. Specific information about the processes:

- name of the processes (coke making, casting, etc.) and annual production
- name of sub-processes (once-through cooling, quenching, etc.)
- water intake flows expressed in m^3/day
- type of water used (seawater, potable, ground-water, etc.)
- flows of water for reuse (where from - where to - daily amount)
- Water discharge (destination: surface water or external sewage works, daily flows).

This section of the survey proved to be particularily difficult to complete. To be able to compare the data from different sites, certain properties had to be specified. The most important carachteristics were:

- Intake water = water from outside of the plant, e.g. freshwater such as potable water, groundwater or seawater.
- Re-use water = water that has been used in one process and is later used in another process (not water circulated within the same process). This part is left open in the survey and users are allowed to qualitatively describe the outflows for reuse, origin and destination.
- Total inflow = total intake + reused water. The total inflow is a number that can be easily compared for the same process at different plants.
- Outflows were divided into discharge to sewage works, discharge to surface water, outflow for reuse, and outflow to "other". The term "sewage works" means an external sewage works as every treatment plant inside the facility is considered a treatment and not a destination. This means that water that is treated in a biological treatment plant and is later discharged to surface water, should be described as an outflow to surface water and the (biological) treatment is to be considered as the post treatment technique.
- “Outflow to other” is the summary of all other destinations.

It should be recognised that significant differences exist between once-through cooling and other processes (make-up for circulating cooling, gas cleaning, etc.).

3. Water treatment techniques employed

This part of the questionnaire asks for all water treatment techniques applied. A clear distinction is made between:

- water pre-treatment techniques and
- water post-treatment techniques.

4. Water quality

This part of the questionnaire asks for the permited values of compounds (concentrations of the most common compounds) in the effluents of different (sub-)processes.

5. Water management efforts

This section is about perceived efforts in water management. With the help of descriptions of different water management issues and levels, participants are asked to assess their own performance (on a scale of 0 to 4) and the importance of water management at their plant.

The different topics are:

- water management and organisation
- water policy
- water metering

- water analyses
- future investment plans
- procurement
- strategic planning
- maintenance.

Analysing the data and development of water flowcharts

Several tools were developed for data analysis and to enable comparisons to be made. During the process it became apparent that it is difficult to compare steel plants with different configurations. It also became clear that it is much more relevant to study the water management on the level of main processes such as cokemaking, casting or hot rolling than at the level of the entire plant.

The working group decided to focus on the main processes and underlying sub-processes. To compare proceses, the data was re-calculated and expressed as water usage in m^3/tonne of product for each process. The loss was calculated automatically based on the inflows and outflows.

All the surveys were individually verified. Unfortunately, many questions and uncertainties remained and the project group therefore decided to add an extra quality improvement step. For each participant a water flowchart was developed to show each participant their completed survey in one single chart. This way mistakes and misinterpretations could easily be identified and each participant was asked additional specific questions to clarify these.

As an example, the flowchart demonstrating the water management system from an integrated steel plant was also circulated. Following this, about 80% off the participants corrected their data. This phase proved a crucial step to improve data quality.

Description of good practices

Initially, the objective of the working group was to identify best practise for water management in the steel industry. Due to the difficulties in making comparisons it became clear that the objective had to be adjusted. A technique that works well for one plant might not be the best option for another plant. Conditions vary considerably and factors such as availability and quality of water play a crucial role.

The unique combination of (sub-)processes made comparison even more difficult. In the surveys received it was not easy to find two comparable configurations. Based on this observation the working group decided to look for good practices instead. Good practices were identified from submissions and participants were asked to describe them in detail.

The descriptions of good practices provided by the participants are listed in the Appendix A of this report. For comparison, the criteria given in the EU Best Reference Documents (BREF) for each process (cokemaking, casting, etc.) are in Appendix B.

Analysing and comparing the final data

The survey was launched and sent to all members of worldsteel in July 2009. Although this was a second attempt and in spite of the global economic crisis it soon became clear that there was significant interest in water management. Finally, data was received from 29 participants, ranging from fully integrated steelworks to plants with only a hot rolling mill.

The following information was extracted from the data:

1. water use expressed in m^3/tonne product for each process and for each steel plant
2. a comparison of steel plant configurations, total production and total water use
3. a comparison of water consumption at the level of the main processes, expressed in m^3/tonne of product and presented in graphs/tables
4. a comparison of the water management efforts of the participants
5. finalised and updated water flowcharts of all the participating steel plants.

In addition to this, the following tools were developed:

6. a software selection tool that can be used to select pre-treatment techniques (on the level of (sub-)processes/type of water/applied techniques, etc.
7. a software selection tool that can be used to select post-treatment techniques (on the level of (sub-)processes/type of water/applied techniques, etc.
8. a software selection tool that can be used to select water quality (on the level of (sub-) processes
9. a database with all the data contributed and derived.

Survey results

General information

This report provides an overview of the water use in 29 steel plants worldwide. It is particularly useful for showing the differences in water use calculated for each of the main processes. For ease of comparison, all results are expressed in m^3/tonne of specific product. For example, the water use of the cokemaking process is expressed in m^3/tonne of coke, in m^3/tonne of pig iron for the blast furnace and in m^3/tonne of cold-rolled steel for the cold rolling mill.

Together, this report and the accompanying water management tool provide information about almost every process in the steel industry. The report presents how water is managed in each of the 29 participating plants, including overviews and detailed information of individual plants and comparisons of sub-processes on various sites.

The project database has information about techniques used for all processes and sub-processes in the different companies. The water management software application can be used to make a selection of these techniques, to select all techniques for a certain company and to select where a specific type of water is used, among other things.

A flowchart was developed for every participating steel plant based on the completed survey. These flowcharts provide an overview of all the main and sub-processes of that plant and its water use. This allows identification of the most comparable configurations.

There are also examples of good practices in this report. Examples for every process were selected by the project working group. The cases included in Appendix A give an overview of water management in the different processes of a steel plant.

Identification of steel plants

To keep the results anonymous, participating steel plants were given a unique identification number from 1 till 29. This identification number is used throughout the report.

Table 2 shows the (process) configuration and the annual production capacity for each process (in million tonnes of product).

Water survey - Overview of processes

Plant number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Steel production in million tonnes/year	5.3	10.2	6.9	0.5	0.3	2.0	4.3	4.6	2.5	5.4	0.8	1.2	0.9	6.3	0.7	0.8	0.1	0.9	4.2	2.8	5.6	6.4	14.9	4.3	2.6	5.5	3.2	4.3	3.3
Cokemaking	2.3	4.2	2.2				1.5		0.7	1.4				3.2					1.3	2.3	2.3	1.4	7.3	1.0	0.9	1.1	1.8	1.3	
Sintering	5.2	13.1	4.4				2.6		2.5	2.7				6.5					5.9	2.4	6.5	8.2	16.3	3.9	2.7	4.7	4.1	5.4	
Pelletising		0.1	4.6																										
Blast furnace	5.1	9.7	6.1				4.0		2.0	4.6				6.6					3.7	2.8	6.3	6.3	13.9	3.9	2.4	4.8	3.1	3.7	
Basic oxygen	5.5	10.4	6.9				4.3		2.4	5.4				6.3					4.2	2.9	5.8	6.3	14.1	4.4	2.6	5.5	3.3	3.9	
Casting	5.3	10.1	6.8			0.7	4.3	4.6	2.4		0.8	1.2		6.1	0.7	0.5		0.9	4.1	2.9	5.6		13.4	4.3	2.6		3.1	3.8	3.3
Hot Rolling	3.5	6.9	4.8	0.5		2.1	3.2	4.7	1.7	5.1	0.7	1.0	0.7	2.5	0.5	0.4	0.1	0.8	4.5	0.6	4.6	4.3	12.6	3.1	2.3		0.6	2.8	3.1
Cold Rolling	0.1	2.7	2.8		0.3	1.1	1.5	1.2		2.7									3.0		1.4		3.3	1.1					0.8
Finishing			0.9		0.2		1.4	0.3		1.0	0.7	0.9		4.6							5.4			0.7					
Corex												0.9																	
Electric arc furnace						0.8		4.6			0.8	1.2	0.9		0.7			0.9					0.9						3.3
Briquetting																							1.0						3.8
Total intake water m³/tonne steel	30.8	6.5	31.0	33.1	0.8	3.7	5.1	70.3	2.3	115.4	5.3	43.4	5.4	69.2	1.5		1.0	1.1	4.7	148.0	6.8	14.8	7.3	33.8	17.5	7.3	80.4	2.7	2.6
Total discharge water m³/tonne steel	28.8	1.5	28.5	31.4	0.6	2.4	2.6	69.5	1.8	110.5	2.6	41.8		66.1	0.8	49.3		0.3	2.8	144.6	2.6	12.9	3.5	28.8	14.8	6.1	77.0		0.6

Table 2: Participating companies' process configuration and production capacity for each process in million tonnes/year

Table 2 also shows the annual production in million tonnes of steel/year as well as the total intake and discharge of water in m^3/tonne of steel. It is important to note that the numbers from different plants cannot be simply compared because of the different plant configurations. Comparisons can only be made at the level of processes. Total numbers can only be compared where the configuration and capacity are similar. Total production ranges from 0.1 (hot rolling only) to 14.9 million tonnes of steel.

Results

Totals and averages

Figure 3 below gives the total production for the 29 participants and the total number of contributions for each process. There are, for example, 17 contributions for the cokemaking process. The 29 participants together produced 110.9 million tonnes of steel in total, This covers approximately 8% of the world's steel production. Most contributions are based on 2008 figures.

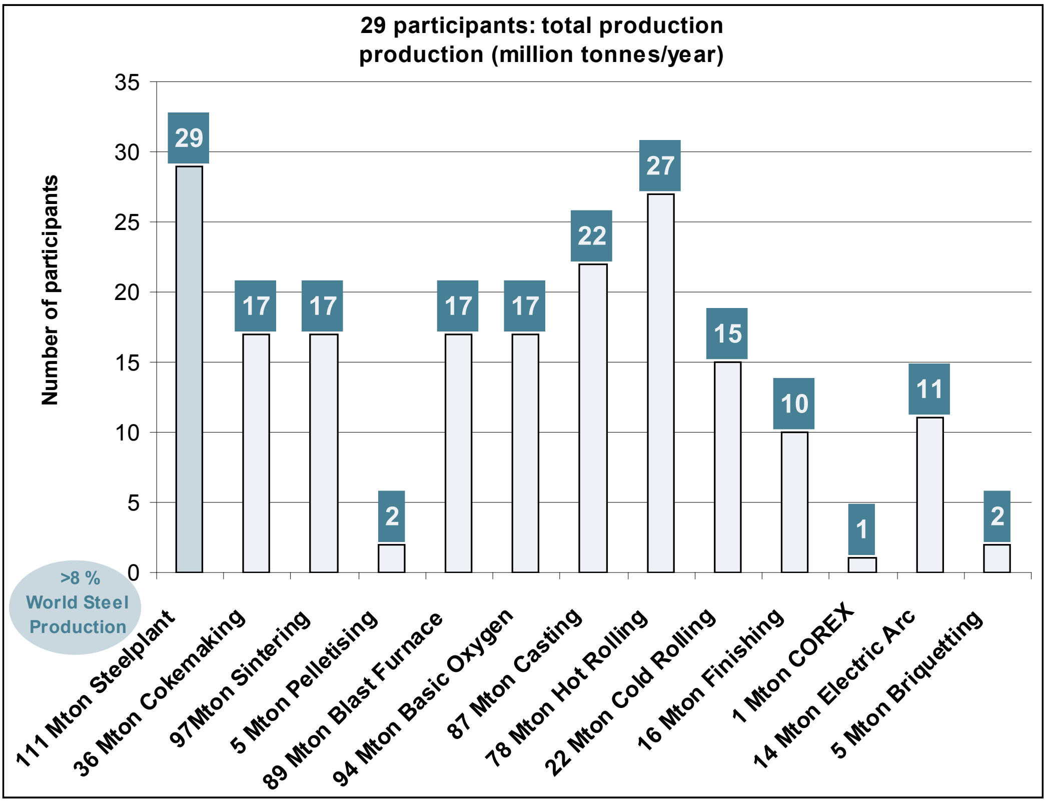


Figure 3: Number of contributions for each process

In the calculations below, data from one participant, plant number 16 (casting, hot rolling and EAF), has been excluded because its flow data could not be balanced. Therefore, the averages used are based on 28 participants. Other information from that participant, such as data on 'management effort' is included.

Table 3 below shows the total water intake and discharge for the 28 companies calculated as the total intake, discharge and loss (sum of all the 28 companies) divided by the total steel production of these companies.

Totals (28 participants)		
Annual steel production: 110 million tonnes		
Annual water intake	3,129,063,984m^3	28.4m^3/tonne steel
Annual water discharge	2,801,462,260m^3	25.4m^3/tonne steel
Annual water loss	297,349,055m^3	2.7m^3/tonne steel

Table 3: Totals and averages

Based on the 28 contributions a few 'Water facts in the steel industry' have been calculated (see Table 4 below). The mass balance is not perfect but estimated to be around 99%. This is mainly due to inaccuracies in the reported reuse flows.

Waterfacts in the steel industry based on the 28 steel plants with a total production of 110 million tonnes			
Annual Intake water	3,129,063,984m^3	28.4 m^3/tonne steel	95.6% from inflow
Annual reuse water	143,920,058m^3	1.3 m^3/tonne steel	4.4% from inflow
Annual inflow water	3,272,984,042m^3	29.7 m^3/tonne steel	-
Annual once-through cooling	2,560,847,489m^3	23.2 m^3/tonne steel	81.8% from intake
Annual discharge sewage	36,547,988m^3	0.3 m^3/tonne steel	1.2% from intake
Annual discharge surface water	2,764,914,272m^3	25.1 m^3/tonne steel	88.4% from intake
Annual total discharge	2,801,462,260m^3	25.4 m^3/tonne steel	89.5% from intake
Annual total loss	297,349,055m^3	2.7 m^3/tonne steel	9.5% from intake

Table 4: Water facts

The totals of water used and discharged varies greatly (see Table 4 above). Consumption (intake[1]) ranges from under 1 to over 148m^3 per tonne of steel produced. The discharge figures follow the consumption figures quite closely, ranking from well under 1 up to 145m^3 per tonne of steel.

The average use and discharge figures for all 29 participating steelworks are 28.4 m^3/tonne and 25.4 m^3/tonne respectively (see Table 3 above).

[1]Consumption=intake for a total plant. For separated processes, consumption=intake+reuse water.

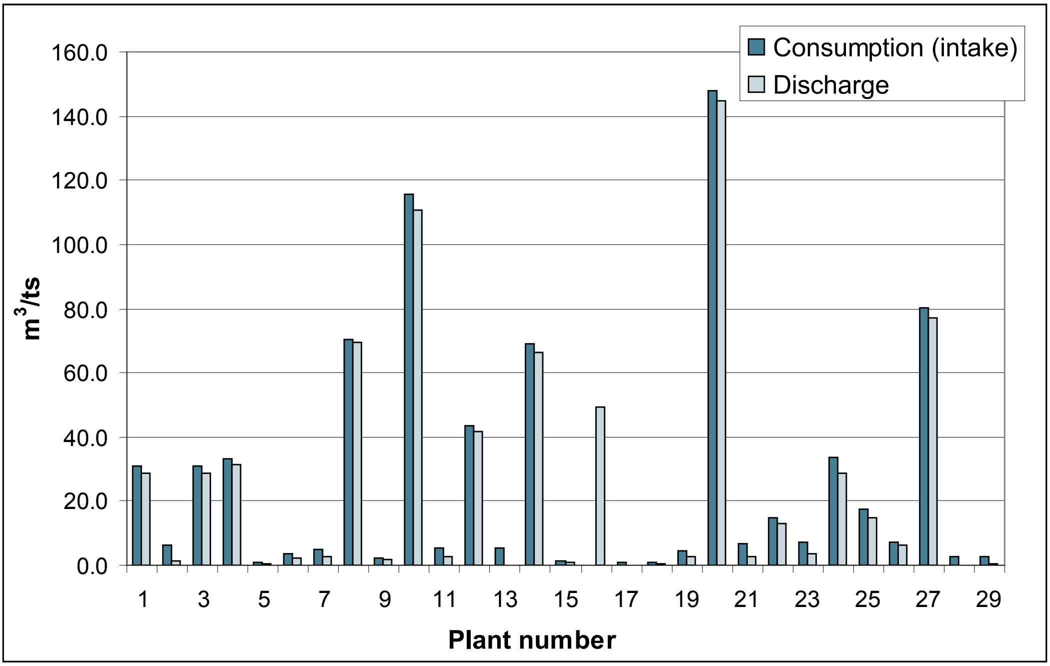


Figure 4: Water consumption versus water discharge

Summary data on water use

Water use data for each participating steel plant is on the accompanying CD. As an example, the water use of plant No. 1 is presented in Table 5 below. For each process the inflows, outflows and losses are calculated in m^3/tonne of product. The (total) production and total water use are also shown. Calculations are based on process-specific information (ie, the sum of sub-processes).

In the tables, a differentiation is made between:

Inflow

- intake water (fresh intake from outside of the plant, for cooling, washing, make-up, etc.)
- reuse water (water already used in another process, NOT circulated (cooling or washing) water)
- inflow total (intake+reuse, this includes water for once-through cooling)
- once-through cooling water.

Outflow

- discharge to external sewage works (not an on-site treatment plant)
- discharge to surface water (treated or non-treated)
- total discharge (discharge to sewage works+discharge to surface water)
- outflow for reuse
- outflow to others (for all other destinations)
- loss (inflow total-outflow total, outflow total being discharge total+outflow for reuse).

Plant 1	Production in million tonnes of steel/year: 5.29 Water use: 30.8 m³/tonne of crude steel										
		INFLOW m³/tonnes				OUTFLOW m³/tonnes					
						Discharge to:					
Process	Production in million tonnes/year	Intake water	Reuse water	Inflow total	Once-through cooling	sewage	surface water	Total discharge	Outflow for reuse	Outflow to other	Loss
Cokemaking	2.33	1.13	0.26	1.39	0.00	0.00	0.00	0.00	0.00	0.00	1.39
Sintering	5.23	0.25	0.14	0.38	0.00	0.00	0.24	0.24	0.05	0.00	0.09
Pelletising	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blast furnace	5.05	6.44	0.08	6.52	5.20	0.00	6.06	6.06	0.03	0.00	0.44
Basic oxygen furnace	5.45	0.17	0.05	0.22	0.00	0.00	0.02	0.02	0.09	0.00	0.11
Casting	5.29	0.34	0.01	0.36	0.00	0.00	0.00	0.00	0.03	0.00	0.33
Hot rolling	3.47	5.35	0.00	5.35	5.05	0.00	5.05	5.05	0.04	0.00	0.27
Cold rolling	.13	0.12	0.00	0.12	0.00	0.00	0.12	0.12	0.00	0.00	0.00
Finishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COREX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electric arc furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Briquetting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest (overall)	5.29	19.86	0.00	19.86	0.00	0.00	19.41	19.41	0.11	0.00	0.34

Table 5: Summary of results from Plant 1

Comparison of the water intake

Different types of water are used in the steel making industry and for different purposes:

- seawater (intake)
- groundwater (intake)
- potable water (intake)
- brackish water (intake)
- other non-potable water (intake)
- reuse water.

Here, a distinction is made between once-through cooling and other processes, such as gas cleaning, quenching, circulation cooling, etc.

Figures 5 and 6 below show the significant differences in water intake in m³/tonne of steel per plant. Bearing in mind the differences in process configuration, the differences in water intake are still large. This emphasises the need to assess the configurations, to find the reasons for the differences in water use.

Here, a distinction is made between once through cooling and processes other than once through cooling such as gascleaning, quenching, circulation cooling etc.

Figure 5 and Figure 6 show the significant differences in water intake in m³/tonne of steel per plant. The differences in process configuration must be kept in mind, but still the differences are large. This emphasises the need to assess the configuration to find the reasons for the differences in water use.

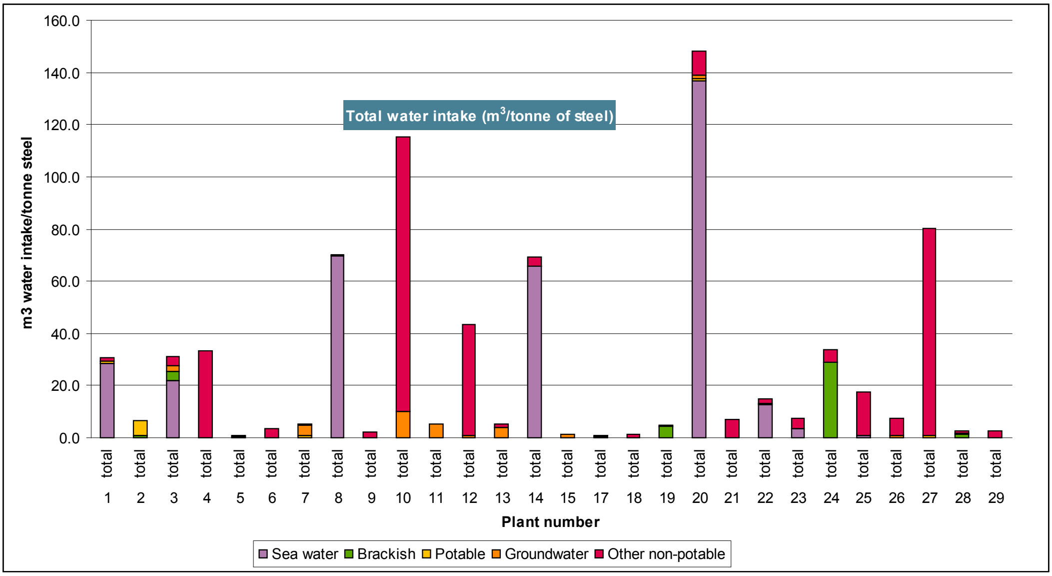


Figure 5: total water intake (m³/tonne of steel), 28 participants

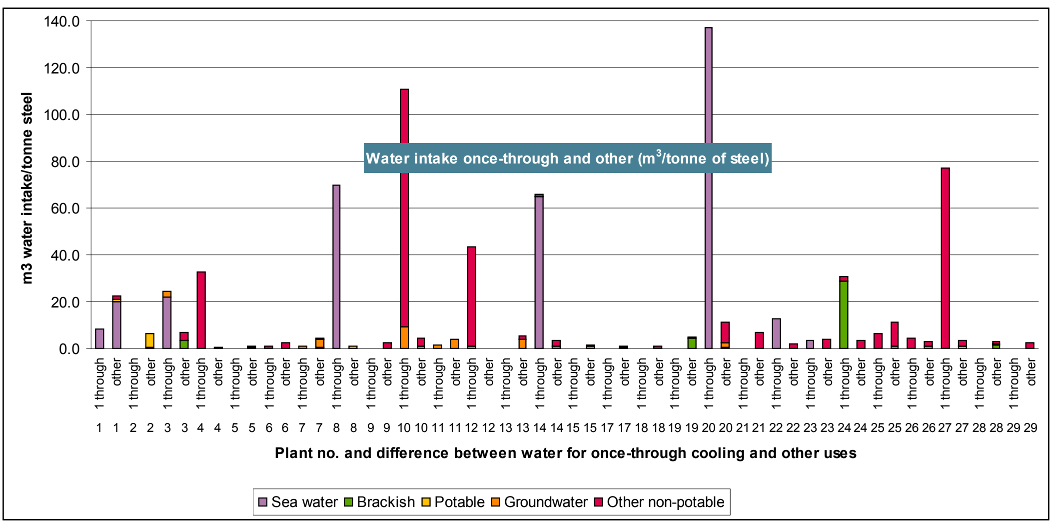


Figure 6: Total water intake (m³/tonne of steel) differentiation between once-through cooloing and other processes, 28 participants

As expected, most of the water is used for once-through cooling. (Note that plant 1 appears to use a lot of water for 'other' processes. Although the data was provided as such, it is most likely that the water is used for once-through cooling.) It is also clear that the type of water used is dependent on factors such as geography and/or cost.

The type of water used determines the pre- and/or post-treatment techniques applied. Figure 7 below shows a sample from an overview chart of all the steel plants and the different types of water used as a percentage of their intake.

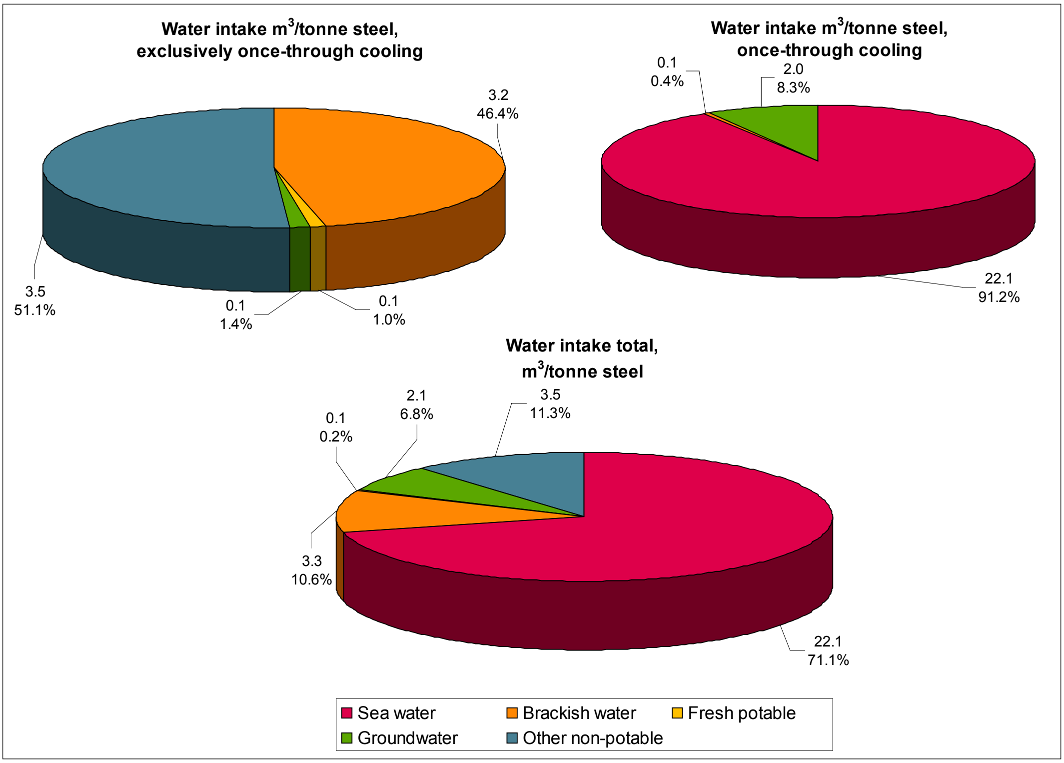


Figure 7: Sample from the 'Overview of water intake' chart - Plant 3

For every plant there are three pie charts that describe:

1. water intake for other processes (not once-through cooling systems)
2. water intake for once-through cooling
3. total water intake, i.e. the sum of 1 and 2.

The complete chart is available from the Excel water management tool on the CD accompanying this report.

Steel production routes

Water use in the three main production routes (described in the Background chapter) cannot be compared because the processes are fundamentally different.

The next few sections of the report compare water use at the 29 steel plants by production route. In total, 17 integrated plants and 10 EAF plants could be compared.

Two companies have both routes. In those cases, it was not possible to make a distinction between the water use for each route, so they are not included under the EAF route. This is because in both companies the EAF production volume is a small part of total production.

Only two plants with a Corex process participated, so there is no specific section on Corex.

The integrated plants

In total 17 integrated steel plants provided data. These plants have all the processes up to BOF for making iron and steel from raw materials (see Table 6 below). Two plants also have an EAF at their site. Steel plant 9's EAF production is <1.3% of its total steel production and steel plant 23's EAF production is <6.3% of its total steel production.

Overview of processes: integrated steel plants, basic oxygen route																	
Plant number:	1	2	3	7	9	10	14	19	20	21	22	23	24	25	26	27	28
Steel production in million tonnes/year	5.3	10.2	6.9	4.3	2.5	5.4	6.3	4.2	2.8	5.6	6.4	14.9	4.3	2.6	5.5	3.2	4.3
Cokemaking	2.3	4.2	2.2	1.5	0.7	1.4	3.2	1.3	2.3	2.3	1.4	7.3	1.0	0.9	1.1	1.8	1.3
Sintering	5.2	13.1	4.4	2.6	2.5	2.7	6.5	5.9	2.4	6.5	8.2	16.3	3.9	2.7	4.7	4.1	5.4
Pelletising		0.1	4.6														
Blast furnace	5.1	9.7	6.1	4.0	2.0	4.6	6.6	3.7	2.8	6.3	6.3	13.9	3.9	2.4	4.8	3.1	3.7
Basic oxygen	5.5	10.4	6.9	4.3	2.4	5.4	6.3	4.2	2.9	5.8	6.3	14.1	4.4	2.6	5.5	3.3	3.9
Casting	5.3	10.1	6.8	4.3	2.4		6.1	4.1	2.9	5.6		13.4	4.3	2.6		3.1	3.8
Hot Rolling	3.5	6.9	4.8	3.2	1.7	5.1	2.5	4.5	0.6	4.6	4.3	12.6	3.1	2.3		0.6	2.8
Cold Rolling	0.1	2.7	2.8	1.5		2.7		3.0		1.4		3.3	1.1				
Finishing			0.9	1.4		1.0	4.6			5.4			0.7				
Corex																	
Electric arc furnace												0.94					
Briquetting												1.0					
Total intake water m^3/tonne steel	30.8	6.5	31.0	5.1	2.3	115.4	69.2	4.7	148.0	6.8	14.8	7.3	33.8	17.5	7.3	80.4	2.7
Total discharge water m^3/tonne steel	28.8	1.5	28.5	2.6	1.8	110.5	66.1	2.8	144.6	2.6	12.9	3.5	28.8	14.8	6.1	77.0	

Table 6: Overview of the participating integrated steel plants' process configuration and production capacity in million tonnes/year

- The smallest of these 17 plants produces 2.5 million tonnes of crude steel.
- The largest of these 17 plants produces 14.9 million tonnes of crude steel.

In Table 7 the same calculations are presented as in Table 3, but only for the 17 integrated plants.

Totals (17 integrated steel plants)		
Annual steel production: 94.8 million tonnes		
Annual water intake	2,706,844,277m^3	28.6m^3/tonne of steel
Annual water discharge	2,403,153,856m^3	25.3m^3/tonne of steel
Annual water loss	272,391,924m^3	2.9m^3/tonne of steel

Table 7: Totals and averages for integrated plants

Based on the 17 results from integrated plants some 'water facts for integrated sites' were calculated (see Table 8 below). The total coverage of the data is not 100% but 99%, mainly because of errors in the reuse flows.

Water facts based on 17 integrated plants with a total production of 94.8 million tonnes			
Annual Intake water	2,706,844,277m^3	28.6m^3/tonne of steel	95.1% from inflow
Annual reuse water	138,215,627m^3	1.5m^3/tonne of steel	4.9% from inflow
Annual inflow water	2,845,059,903m^3	30.0m^3/tonne of steel	
Annual once-through cooling	2,165,353,929m^3	22.8m^3/tonne of steel	80.0% from inflow
Annual discharge sewage	36,389,943m^3	0.4m^3/tonne of steel	1.3% from inflow
Annual discharge surface water	2,366,763,913m^3	25.0m^3/tonne of steel	87.4% from inflow
Annual total discharge	2,403,153,856m^3	25.3m^3/tonne of steel	88.8% from inflow
Annual total loss	272,391,924m^3	2.9m^3/tonne of steel	10.1% from inflow

Table 8: Water facts about the steel industry based on data from integrated plants

In Figures 8 and 9 below the differences between water intake is shown. The lowest intake is 2.3m^3/tonne of crude steel. (0.0% once-through). The highest intake is 148 m^3/tonne of crude steel (92.5% once-through).

Table 8 (above) shows that 4.9% of all the water used for the processes (inflow) is reused water. In almost all cases once-through cooling is only used for one process.

The average of total water used for the processes other than once-through cooling is then: (inflow - once-through cooling) = 7.2m^3/tonne of steel.

Assuming (and this is true in most situations) that all the reused water is not used for once-through cooling, we may conclude that for all the processes, with the exception of once-through cooling, approximately 21% is reused. Altogether, 2.9m^3/tonne of steel or a little more than 10% of the water is lost in the process, for example, through evaporation.

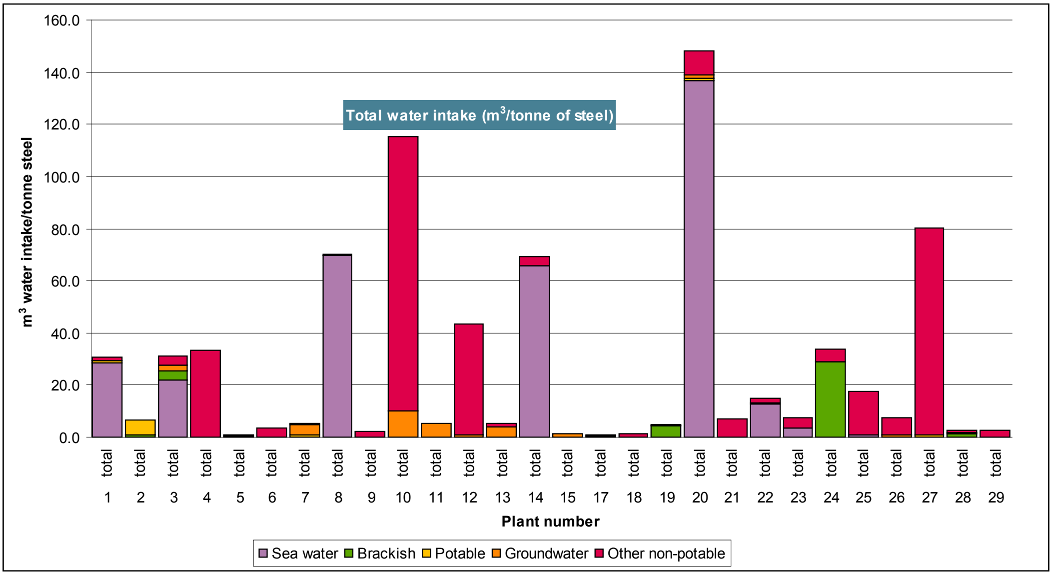


Figure 8: Total water intake (m³/tonne of crude steel) for integrated steel plants

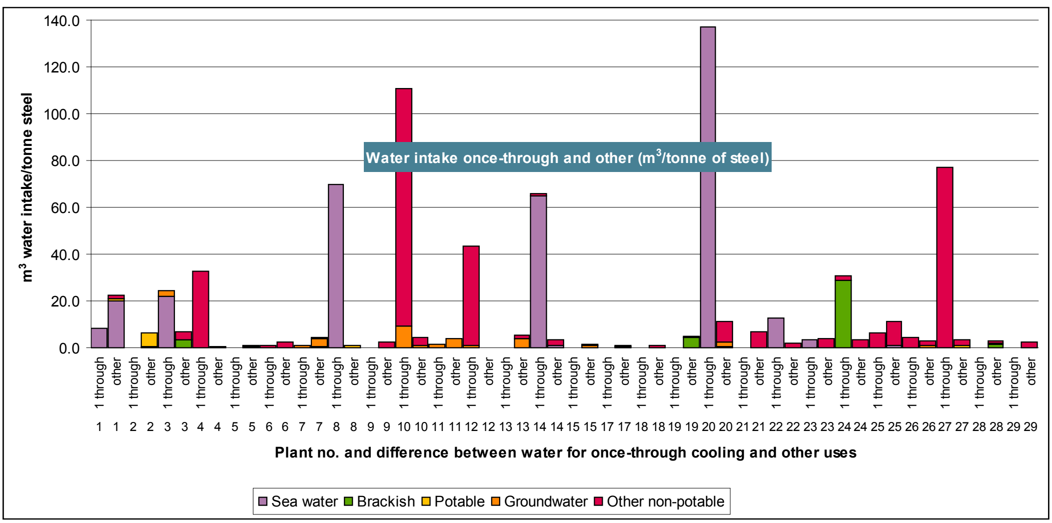


Figure 9: Total water intake (m³/tonne of crude steel) differentiation between once-through cooling and other processes in integrated plants

The EAF route

A total of 10 steel plants with an EAF provided data. For two plants that also produce steel in the integrated route, the percentage EAF versus total production is very small, and a distinction in water use is not possible. Therefore, these two have been excluded from the EAF comparison.

In total, eight plants are compared in this EAF section (see Table 9 below).

Overview of processes: EAF route								
Plant number:	6	8	11	12	13	15	18	29
Steel production in million tonnes steel/year	2.0	4.6	0.8	1.2	0.9	0.7	0.9	3.3
Casting	0.7	4.6	0.8	1.2		0.7	0.9	3.3
Hot Rolling	2.1	4.7	0.7	1.0	0.7	0.5	0.8	3.1
Cold Rolling	1.1	1.2	0.0	0.0	0.0	0.0	0.0	0.8
Finishing	0.0	0.3	0.7	0.9	0.0	0.0	0.0	0.0
Corex	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
EAF	0.8	4.6	0.8	1.2	0.9	0.7	0.9	3.31
Briquetting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8
Total intake water m^3/tonne of steel	3.7	70.3	5.3	43.4	5.4	1.5	1.1	2.6
Total discharge water m^3/tonne of steel	2.4	69.5	2.6	41.8	0.0	0.8	0.3	0.6

Table 9: Overview of the participating EAF steel plants' process configuration and production capacity in million tonnes/year

The smallest of the eight plants produces 0.7 million tonnes of crude steel. The largest produces 4.6 million tonnes of crude steel.

Totals (8 EAF steel plants)		
Annual steel production: 14.4 million tonnes		
Annual water intake	405,188,442m^3	28.1m^3/tonne of steel
Annual water discharge	382,296,584m^3	26.5m^3/tonne of steel
Annual water loss	23,937,686m^3	1.7m^3/tonne of steel

Table 10: Totals and averages for EAF plants

The calculated values are based on the data provided. As with the integrated route data, the balance is not completely 100%. This is mainly due to small errors in the reuse flows.

Based on the results from eight EAF plants, some 'water facts for EAF sites' were calculated (see Table 11 below).

Water facts based on eight EAF plants with a total production of 14.4 million tonnes			
Annual Intake water	405,188,442m^3	28.1m^3/tonne of steel	99.4% from inflow
Annual reuse water	2,559,592m^3	0.2m^3/tonne of steel	0.6 from inflow
Annual inflow water	407,748,034m^3	28.2m^3/tonne of steel	
Annual once-through cooling	377,623,160m^3	26.2m^3/tonne of steel	93.2 from inflow
Annual discharge sewage	158,045m^3	0.0m^3/tonne of steel	0.0 from inflow
Annual discharge surface water	382,138,539m^3	26.5m^3/tonne of steel	94.3 from inflow
Annual total discharge	382,296,584m^3	26.5m^3/tonne of steel	94.4 from inflow
Annual total loss	23,937,686m^3	1.7m^3/tonne of steel	5.9 from inflow

Table 11: Water facts about the steel industry based on data from EAF plants

In Figures 10 and 11 below the differences between the water intake is shown. The lowest intake is 1.1m³/tonne of crude steel. (0.0% once-through). The highest intake is 70.3m³/tonne of crude steel (98.8% once-through). The differences are mainly due to whether or not once-through cooling systems are used. What stands out is the extreme differences in water use.

Another conclusion is that 0.6% of all the water used for the different processes (inflow) is reused water. In nearly all situations, once-through cooling water is used for one process only. The average total of water used for different processes other then once-through cooling is then: (inflow - once through cooling) = 2.0m³/ tonne of steel.

Assuming (and this is true in most situations) that the reused water is not used for once-through cooling, we can conclude that for all the processes, with the exception for once-through cooling, approximately 10% is reused. Altogether, 1.7m³/tonne of steel or 6% of water per tonne of steel produced is lost (by evaporation or through leaks).

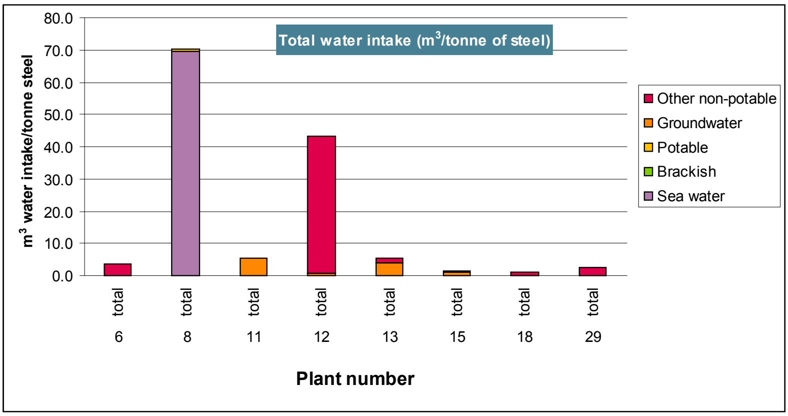


Figure 10: Total water intake (m³/tonne of crude steel) for EAF steel plants

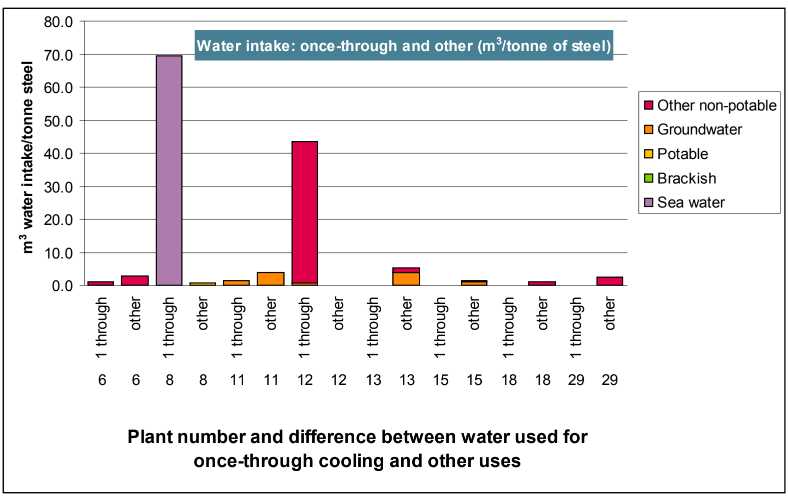


Figure 11: Total water intake (m³/tonne of crude steel) differentiation between once-through cooling and other processes in EAF plants

Water use in steelmaking processes

Breaking down total water use into the individual processes (intake + reuse for a specific process), it becomes evident that there are significant differences among the averages for different facilities per tonne of product (note: not per tonne of steel produced).

Figure 12 below shows that a great deal of the water is not being used by the actual processes, but rather their supporting functions, labelled as 'rest' in the graph, which often includes power generation, equipment cooling, and so on.

Figure 12 presents averages. It must be taken into account that the number of entries differs for each process. Therefore, it is not possible to compare the different processes. For instance, there is only one participants using Corex, a process that uses a relatively large amount of water (18.1 m^3/tonne of Corex steel) while the average from the next "bulk user", the blast furnace, uses an average of 5.7 m^3/tonne of hot metal.

In total, 17 participants submitted blast furnace data. The lowest use was 0.2m^3/tonne of hot metal and the highest use was 28.2m^3/tonne of hot metal.

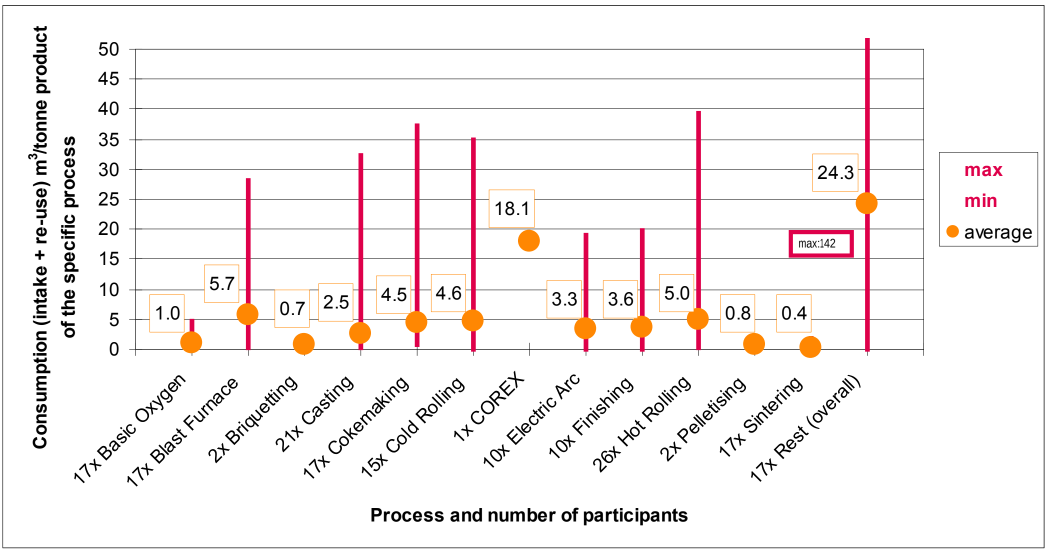


Figure 12: Average and range of water use for each process

Each process can be compared easily and these comparisons provide valuable information. For example, it can show why is one company able to use only a very small amount of water while another company uses much more for production of the same product.

In the following section of the report, differences in water use (inflows and outflows) for each process are explored. The water management tools provided on the accompanying CD reveal further information about the processes, water flows, the used techniques and much more.

For every process, charts have been created showing the water inflows and outflows. All charts can be found in on the CD that accompanies this report.

For water inflows a distinction is made between:

- intake water including once-through cooling
- reuse water
- inflow total (reuse + intake)
- once-through cooling.

The second chart shows the water outflows and distinction is made between:

- discharge to a external sewage works
- discharge to surface water
- total discharge (discharge to surface + discharge to surface water)
- outflow for reuse
- other outflow
- loss.

In some cases an inflow or an outflow is so high in comparison to others that the graph exceeds the borders of the chart. In these cases the value is displayed in red in a separate box.

Examples of the charts in the accompanying CD are show in Figures 13 and 14, below.

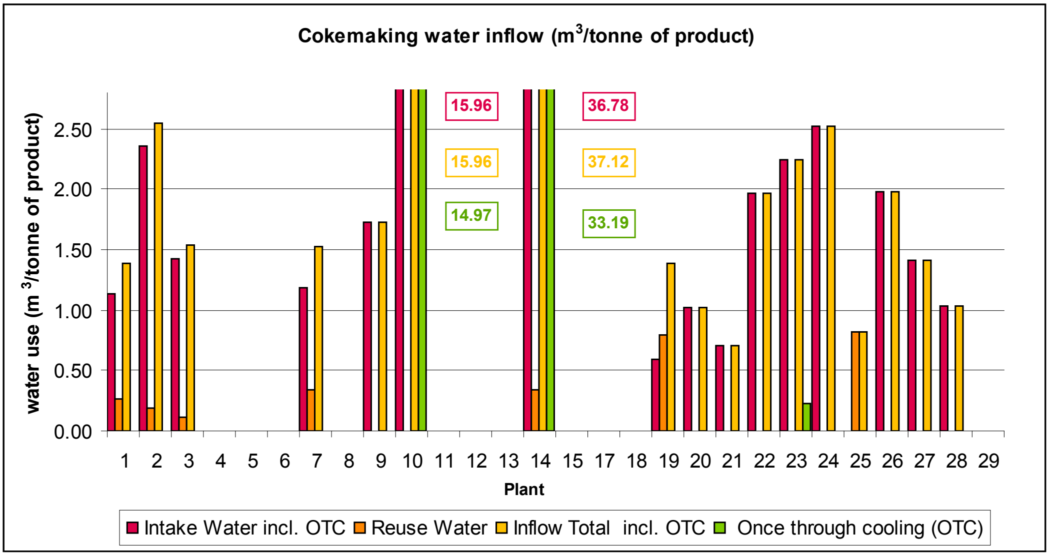


Figure 13: Sample comparision chart for processes in different plants, water intake

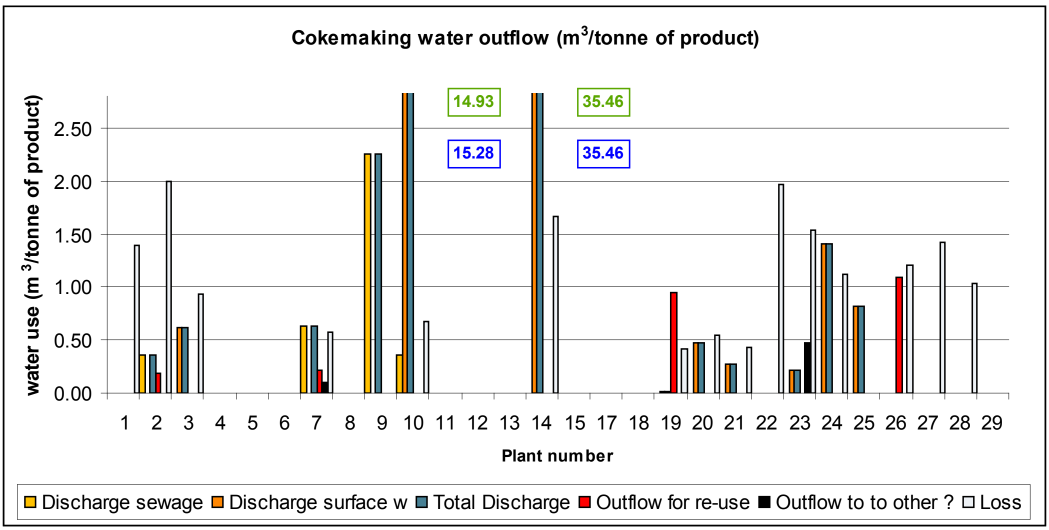


Figure 14: Sample comparison chart for processes in different plants, water outflow

When using these charts, it is important to note that overlaps are possible. For example, water used for different processes is placed under one process or the process "rest" (the space in the survey where a participant could document anything). All the original data is in the water management tool.

The conclusions for each process are shown in Tables 12 and 13 below. These tables contain the averages and the minimum and maximum for each significant water flow per process.

Cokemaking						
	Intake	Re-use	Inflow	Once-through	Total discharge	Loss
Plant number	17	17	17	17	17	17
Max m³/tonne of product	36.8	0.8	37.1	33.2	35.5	2.0
Min m³/tonne of product	0.0	0.0	0.7	0.0	0.0	0.0
Average m³/tonne of product	4.4	0.2	4.5	2.8	3.4	1.0
Sintering						
Plant number	17	17	17	17	17	17
Max m³/tonne of product	1.8	0.4	1.8	1.6	1.8	0.7
Min m³/tonne of product	0.0	0.0	0.0	0.0	0.0	0.0
Average m³/tonne of product	0.3	0.0	0.4	0.2	0.2	0.1
Pelletising						
Plant number	2	2	2	2	2	2
Max m³/tonne of product	1.1	0.0	1.1	0.2	1.0	0.2
Min m³/tonne of product	0.5	0.0	0.5	0.0	0.3	0.1
Average m³/tonne of product	0.8	0.0	0.8	0.1	0.6	0.1
Blast furnace						
Plant number	17	17	17	17	17	17
Max m³/tonne of product	28.0	3.4	28.2	23.7	27.0	1.6
Min m³/tonne of product	0.0	0.0	0.2	0.0	0.0	0.0
Average m³/tonne of product	5.3	0.4	5.7	4.3	4.8	0.6
Basic oxygen						
Plant number	17	17	17	17	17	17
Max m³/tonne of product	3.5	3.7	4.8	3.3	3.4	1.2
Min m³/tonne of product	0.1	0.0	0.1	0.0	0.0	0.1
Average m³/tonne of product	0.7	0.3	1.0	0.2	0.4	0.3
Casting						
Plant number	21	21	21	21	21	21
Max m³/tonne of product	32.2	0.6	32.2	31.9	31.9	0.6
Min m³/tonne of product	0.1	0.0	0.1	0.0	0.0	0.0
Average m³/tonne of product	2.5	0.1	2.5	2.0	2.2	0.3
Hot rolling						
Plant number	26	26	26	26	26	26
Max m³/tonne of product	33.1	6.2	39.4	35.4	31.4	3.4
Min m³/tonne of product	0.0	0.0	0.3	0.0	0.0	0.1
Average m³/tonne of product	4.6	0.4	5.0	3.6	4.0	0.7

Table 12: Processes - summary table, part 1

Cold rolling						
	Intake	Re-use	Inflow	Once-through	Total discharge	Loss
Plant number	15	15	15	15	15	15
Max m³/tonne of product	35.0	2.0	35.0	35.0	35.0	3.3
Min m³/tonne of product	0.1	0.0	0.1	0.0	0.0	0.0
Average m³/tonne of product	4.5	0.2	4.6	3.2	3.5	0.6
Finishing						
Plant number	10	10	10	10	10	10
Max m³/tonne of product	19.7	0.3	19.7	19.6	19.5	1.2
Min m³/tonne of product	0.0	0.0	0.0	0.0	0.0	0.0
Average m³/tonne of product	3.6	0.0	3.6	3.1	3.3	0.3
Corex						
Plant number	1	1	1	1	1	1
Max m³/tonne of product	18.1	0.0	18.1	18.1	18.1	0.0
Min m³/tonne of product	18.1	0.0	18.1	18.1	18.1	0.0
Average m³/tonne of product	18.1	0.0	18.1	18.1	18.1	0.0
Electric arc						
Plant number	10	10	10	10	10	10
Max m³/tonne of product	19.0	0.0	19.0	18.8	18.8	2.7
Min m³/tonne of product	0.1	0.0	0.1	0.0	0.0	0.0
Average m³/tonne of product	3.3	0.0	3.3	2.0	2.1	0.8
Briquetting						
Plant number	2	2	2	2	2	2
Max m³/tonne of product	1.1	0.2	1.2	0.0	0.3	0.9
Min m³/tonne of product	0.1	0.0	0.1	0.0	0.0	0.1
Average m³/tonne of product	0.6	0.1	0.7	0.0	0.2	0.5
"Rest" (Overall)						
Plant number	17	17	17	17	17	17
Max m³/tonne of product	142.4	7.2	142.4	136.9	141.8	3.4
Min m³/tonne of product	0.0	0.0	0.0	0.0	0.0	0.0
Average m³/tonne of product	23.9	0.5	24.3	21.2	22.8	0.9

Table 13: Processes - summary table, part 2

Water quality

This part of the survey proved difficult. Some participants could not complete this section due to lack of reliable data or did not wish to provide the information.

For every type of water discharge, participants could provide information about the actual emission concentrations and the limit values for the components that generally are an issue in the steel industry.

A component of the water management tool allows users to select a specific process and to show which sites provided what information.

Water flowcharts

For each of the steel plants a water flowchart that shows all the processes, the sub-processes and the amount of water entering and leaving the systems was created. In the flowcharts, a distinction is made between the different types of water as well as different flows.

The flowcharts provide all the information in one spreadsheet. This makes it easy to see if the water balance is correct. In this way the flowcharts can be used to check the quality of information submitted.

The flowcharts are available on the CD together with the water management tool.

The flowchart gives an overview of a steel plant; its configuration and the water used for each process. Water in- and outflows are expressed in m^3/tonne of product for each main and sub-process based on the “process water data” sheet from the survey. The difference between inflow and outflow is automatically calculated as “loss” and contains everything that is not discharged or reused. If all the data submitted is correct, every inflow and outflow has a start- and end-point.

At the bottom of each sheet the totals for intake (inflow without reuse water) and outflow (without reuse water) are presented. A difference between total intake and total outflow may be observed and is mainly due to the phenomenon that the outflow for reuse is larger than the inflow for reuse.

Techniques applied

Different techniques are applied for pre-treatment processes and post-treatment processes:

- A pre-treatment technique is used to achieve water quality suitable for use in a certain process.
- A post-treatment technique is used to improve the water quality up to a satisfactory level for it to be discharged (or reused).

For every flow the participants were asked to state which techniques are applied. The techniques used depend on:

- the type of (sub-)process, because each type of process requires a specific water quality
- the type of water used, because each type of water has its own chemical characteristics
- the configuration of the plant (logistics, possibility for reuse, etc.)
- legislation.

Since the techniques applied depend on several factors, it is not possible to draw conclusions on best available techniques.

A software tool was developed to enable selection of techniques for specific situations. It can be used, for example, to optimise processes by checking existing solutions in similar situations.

Pre-treatment

The following techniques are used for pre-treatment:

Biological control or disinfection of non-potable water

Raw waters, like river or seawater contain micro-organisms such as bacteria, algae, fungi, viruses and higher organisms. To prevent biological fouling such as formation of bioflims, biological control can be performed by chemical or physical treatment methods like chlorination (most commonly used) and dosing of other biocides or UV light radiation and membrane filtration.

Demineralisation

Through demineralisation, dissolved minerals are removed from water (almost) completely. There are various ways to demineralise water, including distillation, deionisation, membrane filtration (reverse osmosis or nanofiltration) and electrodyalisis.

Desalination

Desalination is the removal of salts from sea or brackish water to produce freshwater. Techniques used include reverse osmosis, membranes and ion-exchange.

Distillation

Distillation is the process of vaporising a liquid and recovering it by condensing the vapour. The liquid formed by this condensation is called distillate.

Filtration

Mechanical separation of a solid phase or semi-solid phase from a fluid is called filtration. Sand filtration and other conventional techniques are commonly applied. Membrane filtration is used more and more frequently.

Reverse osmosis

Osmosis is based on the principle that two fluids containing different concentrations of dissolved solids that come in contact with each other will mix until the concentration is uniform. When these two fluids are separated by a semi-permeable membrane (which lets the fluid flow through, while dissolved solids stay behind), the fluid containing the lower concentration will move through the membrane into the fluid containing the higher concentration of dissolved solids. After a while the water level will be higher on one side of the membrane. The difference in height is called the osmotic pressure.

By applying a pressure that exceeds this osmotic pressure, the reverse effect of osmosis occurs. Fluids are pressed back through the membrane, while dissolved solids stay behind.

To purify water by reverse osmosis membranes, the natural osmosis effect must be reversed. To force the water of the brine stream (high salt concentration) to flow towards the fresh stream (low salt concentration), the water must be pressurised at an operating pressure greater than the osmotic pressure. As a result, the brine side will become more concentrated. High pressure is needed to exceed the osmotic pressure (for seawater, this is approximately 60 bar).

Softening

This refers to the removal of calcium and magnesium ions, sometimes also iron ions, that make the water hard and thereby changing the deposition at higher temperature considerably.

Post-treatment

The following techniques are used for post-treatment, this is, improving water quality from treated wastewater to a level that can be discharged or reused:

- Activated carbon adsorption – a process where a solid is used to remove a soluble substance from water. Activated carbon is produced specifically to achieve a very large internal surface (between 500 and 1500 m^2/g). This internal surface makes active carbon ideal for adsorption.
- Aeration – providing oxygen in sewage and waste effluent to oxidise organic and inorganic material respectively.
- Biological treatment (for example, activated sludge) – removal of organic components from wastewater. Two main categories can be defined: aerobic treatment and anaerobic treatment, processes using oxygen and processes under anoxic circumstances respectively.
- Clarifier and classifier – basins where water has a certain retention time, long enough to make it possible for (organic) solids to settle. The concentrated solids have to be handled separately.
- Cooling pond and cooling tower – a cooling pond is a man-made water body primarily for the purpose of providing cooling water. Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere based on natural draft and mechanical draft.
- Demineralisation – See above, 'Pre-treatment'.
- Desalination – See above, 'Pre-treatment'.
- Dissolved air flotation – is usually used as a polishing step after physical-chemical treatment and is used to remove smaller particles that cannot settle fast enough in conventional settling processes. Flotation can be divided into three types: natural, aided and induced flotation.
- Distillation – See above, 'Pre-treatment'.
- Equalisation – the process of controlling hydraulic velocity, or flow rate, through a wastewater treatment system. Flow equalisation prevents short-term, high volumes of incoming flow, called surges, from forcing solids and organic material out of the treatment process.
- Evaporation – the conversion of a liquid into a vapour for the purpose of separating it from another liquid of higher boiling point, or from a solid which is dissolved in it.

- Filtration – See above, 'Pre-treatment'.
- Flocculation and coagulation – Coagulation is the destabilisation of colloidal particles brought together by the addition of a chemical reagent (most of the times a polymer-type of chemical) called coagulant. Flocculation is the agglomeration of destabilised particles into microflocs and bulky flocs which can be removed from the water by settling. The addition of a specific reagent called flocculant or flocculant aid may promote the formation of the flocs.
- Heat exchange – heated water is cooled by an indirect cooler before the water is discharged, circulated or reused. These coolers are known as heat exchangers.
- Lagoon – a natural treatment technique that consists of the accumulation of wastewater in ponds or basins, known as biological or stabilisation ponds, where a series of biological, biochemical and physical processes take place.
- Neutralisation and pH adjustment – by adding an acid or basic solution water can be neutralised (pH-value = 7.0).
- Oil/water separation – by using a separator (tank), oil floats and clean water can be separated from the mixture. There are many different types of separators to improve separation effenciency and the quality of the water.
- Reverse osmosis – See above, 'Pre-treatment'.
- Sedimentation – or settling is the separation of suspended solids that are heavier than water. This process is based on the differences in density between particles and the fluid. Sedimentation is widely used in wastewater treatment systems. Different kind of sedimentation tanks can be used.
- Sludge dewatering – can be done naturally (dry beds, solar drying) when there is enough time and space. Faster and smaller, but also more cost intensive, are machine processes such as pressing (filter press) and centrifugation (centrifuge).
- Softening – See above, 'Pre-treatment'.

Water management efforts

Survey participants were asked to carry out an assessment of water management efforts within their organisation. The purpose of this 'water management matrix' was to get an overview of the qualitative water management issues within the steelworks and report them in a quantitative manner to enable comparison between the steelworks.

The matrix is divided into 10 sections, covering the topics deemed by the working group to be the most important for water management within steelworks. The matrix works in a five-step scale, rating the level of water management in specific areas within the organisation. The topics rated are:

- water management and organisation
- water policy
- water metering
- water analyses
- future investment plans
- procurement
- strategic planning
- maintenance
- reporting.

In the water management matrix (see Table 14 below) each plant rates its water management efforts with scores between 0 and 4. Score 0 represents a low level of water management within the specific area. It refers to 'unclear responsibilities' under the section 'Water Manager and Organisation or 'no policy' under the Water Policy section and 'nil' under the section Future Investment Plans.

Score 4 reflects high water management efforts within the organisation. Under the section Water Manager & Organisation, score 4 refers to having at least a 'full-time water manager and high powered water committee'. Under the section Water Policy it refers to having a 'formal water policy, regular reviews and commitment of top management'. Under the section Water Analysis, score 4 refers to 'extensive metering on all the steelworks' facilities and water metering data reported'.

All the individual sections of the water management matrix with their respective scoring are shown in Table 14.

The water management matrix self-assessment scores of all the survey participants with respective plant numbers, together with averaged involvement with water management converted in percentages (on a scale 0-100 %) are presented in Table 15.

	0	1	2	3	4
Water Manager & Organisation	Unclear responsibilities	Part-time water manager with limited authority or influence	Clear responsibilities with part-time water manager	Dedicated, full-time water manager with influence and power	Full-time water manager & high powered water committee
Water Policy	No policy	An unwritten set of guidelines	Policy referenced in environmental or other policies	Formal water policy, but no active review process	Formal water policy, regular reviews and commitment of top management
Water Metering	Billing meters	Billing meters with limited sub-metering (e,g, potable water meters only)	Substantial metering and submetering	Substantial metering and submetering, Water metering reporting party/ division	Extensive metering on all the Steelworks' facilities, Water metering data reported
Water Analysis	Meters checked against utility bills	Some analysis, reference to historical consumption	Water performance reports issues internally	Water performance compared against historical data and benchmarking	Advance automated monitoring and targeting with alarming & trend analysis
Future Investment Plans	Nil	Anything with quick payback	Capital spending on replacements only	Some planned investments to reduce water consumption and/or improve water efficiency	Major planned investment(s) to reduce water consumption and/or improve water efficiency
Procurement	Water efficiency not considered when purchasing new plant/ equipment	Water efficiency occasionally taken into consideration in new purchases	Water efficiency considered on utility plant only e,g, water treatment plant, etc.	Procurement policy provides clear guidance on water consumption for new purchases	Procurement policy including water and environmental performance
Strategic Planning	Water management planning is short term only	Strategic planning for water management is long term but isolated form the other planning processes	Water management only loosely associated with overall strategic planning	Water management function is clearly established but not fully integrated into strategic planning	Full strategic plan for water in place with time scales and resources agreed and allocated
Maintenance	No maintenance plan, Leaks fixed when resources become available, (Very low priority)	Periodic maintenance inspections, Leaks are given low priority,	Maintenance plan exists, Some preventative maintenance carried out, Leaks are given moderate priority	Comprehensive preventative maintenance and inspection plan, Leaks are given high priority,	Comprehensive preventative maintenance and inspection plan, Leaks received special priority and resources,
Reporting	No periodic reporting of water statistics to senior technical or operations management	Annual reporting of water issues to senior technical or operations management eg, Manager Steelmaking	Monthly reporting of water issues to senior technical or operations management eg, Manager Steelmaking	Weekly reporting of water issues to senior technical or operations management eg, Manager Steelmaking	Daily reporting of water issues to senior technical or operations management eg, Manager Steelmaking

Table 14: Water management matrix

Results

As shown in Table 15 below, the average score for the water management efforts of the survey participants was 67%. The lowest score is 31% and highest is 94%. Looking at the average scores for specific areas, the steelworks rated themselves poorly for Reporting (48%) and Procurement (63%). The highest scores were for Maintenance and Future Investment Plans (both 72%).

When looking at the overall scores for different areas of water management, two, namely Future Investment Plans and Maintenance, were scored highest throughout the steelworks (73%). Altogether nine steelworks gave themselves the maximum score of 4 in the area of Future Investment Plans, indicating that water is likely to be high on many agendas. Maintenance also scored well, but more importantly there were no 0 scores and only one 1, out of 29 steelworks. As expected, maintenace is deemed important in many of the steelworks.

On the other hand, there are few areas of water management that scored lower overall, such as Procurement. It is interesting to see that steelworks that score very well overall have only given themselves a 2 here. Water efficiency considered only when investing in equipment relating to utilities, such as water treatment plants. This indicates that in many plants, water efficiency is not considered or considered only slightly when investing in any non-utility related equipment, including production related equipment.

PLANT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Avg
Water Manager & Organisation	3	3	3	1	2	1	4	4	3	3	2	3	3	3	2	2	3	2	1	3	2	3	4	3	2	4	2	3	2	2.6
Water Policy	3	4	3	1	2	1	3	3	2	4	2	2	2	4	1	4	4	2	3	2	2	3	4	1	2	4	2	4	4	2.7
Water Metering	3	3	4	0	3	0	4	2	3	4	3	2	3	4	2	2	2	2	3	4	1	2	4	2	2	3	3	0	4	2.6
Water Analysis	3	3	4	1	2	1	4	1	3	4	3	2	2	4	4	3	3	3	4	2	1	3	4	2	2	3	3	4	3	2.8
Future Invest-ment Plans	3	4	2	3	0	4	2	4	3	3	3	3	3	4	4	2	2	3	0	3	3	3	4	4	4	3	0	3	4	2.9
Procurement	3	3	2	2	3	1	2	4	4	3	3	4	3	4	1	2	3	0	2	3	2	4	3	1	2	2	2	3	2	2.5
Strategic Planning	4	4	3	2	2	2	2	3	4	4	3	3	3	4	3	2	3	4	1	0	2	3	4	2	1	3	0	3	3	2.7
Maintenance	4	4	2	2	3	1	2	4	2	3	3	4	3	3	4	3	3	3	2	2	4	4	3	2	2	3	2	2	4	2.9
Reporting	3	4	3	0	2	0	4	1	3	4	2	2	2	4	2	3	3	3	1	2	2	3	4	1	2	3	2	2	4	2.4
Involvement with water (%)	81	89	72	33	53	31	75	72	75	89	67	69	67	94	64	64	72	61	47	58	53	78	94	50	53	78	44	67	83	67

Table 15: Summary of the water management self-assessment

Figure 15 below shows that all 29 scores detailing the percentage of involvement with water management are actually equally divided between these scores, even though there is a large difference between the lowest and the highest score. There are no great jumps between individual scores. Rather, the scores rise cumulatively throughout the graph.

This indicates that there are not just steelworks that place great or little importance on their water management, but that all are distributed between the two extremes.

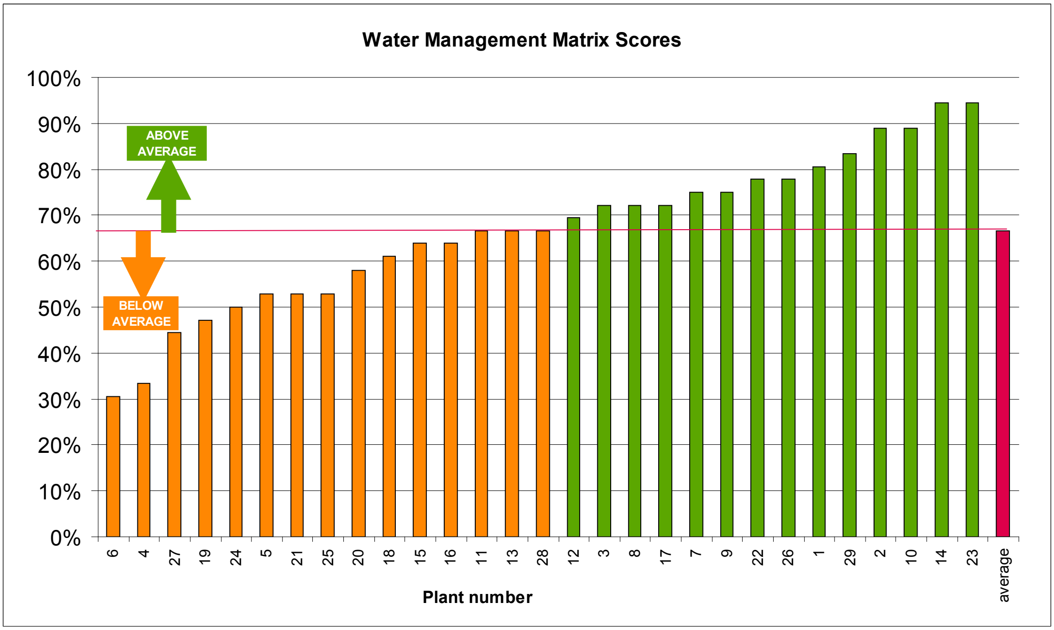


Figure 15: Water management matrix results per plant

In any survey, the answers given will depend on many factors including respondents' motivation, memory, ability to respond and so on. They might be motivated to give answers that present themselves in a favourable light. In this survey, companies are not identified. The fact that participants rated their water management efforts with a high average of 67% may be an indication that participating companies are more active with their water management efforts and might not directly reflect the water management efforts of the entire steel industry.

Good practices

At the final meetings of the water management working group it was agreed that a significant part of the project report should describe examples of current water practices. Efficiently applied water treatment technologies and good water management are inextricably linked. The examples have been chosen on the basis of the descriptions given in the surveys by the participating companies. The water treatment practices from these companies is transferable to the iron and steel industry in general.

Selected companies were asked to describe one or more of their processes in greater detail, covering the following aspects:

- the purpose of the water used
- which method is applied for pre- and/or post-treatment of the water
- description of the processes and treatment methods applied
- a simplified flow diagram, and if available, pictures of the water treatment installations
- amounts treated, removal efficiencies, capacities, design criteria, etc.
- quality of treated water
- chemicals used, waste production
- any additional information that could be useful for the water management project.

Contributions were received from:

- Four coke plant water treatment installations (China Steel, ArcelorMittal Tubarao, Tata Steel IJmuiden and voestalpine)
- One blast furnace water treatment plant (Oydak Isdemir)
- One water treatment plant at a pelletising plant (Tata Steel IJmuiden)
- One water treatment plant at a sinter plant (voestalpine)
- Four water treatment plants at basic oxygen steel plants (BlueScope Port Kembla, Trinecke Zelezarny, Oydak Isdemir and Tata Steel IJmuiden)
- Five hot-rolling mill water treatment plants (BlueScope Port Kembla, Tenaris Tamsa, CMC Steel Arkansas, Tata Steel Europe Port Talbot and China Steel)
- Three cold-rolling water treatment plants (Duferco La Louvière, ArcelorMittal Ghent and China Steel)
- One water treatment plant at a finishing/galvanising plant (voestalpine)
- Two DRI Midrex water treatment plants (Tenaris Siderca and Essar Steel)
- Four descriptions of integrated water treatment plants (POSCO Pohang Steel Works, China Steel, Tenaris Dalmine and Tata Steel IJmuiden).

The data from the plants listed above give a representative image of the level of water treatment in the global steel industry.

All the contributions are brought together in Appendix A. Information on the water treatment plants is summarised per process. Appendix B has information about best available techniques (BAT) as described in the EU Directive on Integrated Pollution Prevention Control (IPPC).

The term 'best available technique' is defined as “the most effective and advanced stage in the development of activities and their method of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole”.

The purpose of the directive is to achieve integrated prevention and control of pollution arising from industrial activites and leading to a high level of protection of the environment. All steel plants in the EU must comply with the provisions in the directive and have to implement BATs.

The relevant BAT reference documents are:

- Draft Reference Document on Best Available Techniques for Iron and Steel Production (Draft, October 2010)
- Best Available Techniques Reference Document in the Ferrous Metals Processing Industry (December 2001).

Conclusions

The study clearly shows that water is an important issue for the steel industry and will become even more so in the future. Water shortages and poor water quality can jeopardise steel production, and these issues need further attention. Furthermore, water management is an important part of the steel industry's sustainability roadmap. And its image is affected by the way it manages this scarce resource.

Water issues and the how they are managed at specific plants vary greatly due to local aspects such as water availability, water quality, plant configuration and legislation. Therefore, the data presented in this report cannot be generalised. It presents a picture of the situation as it is, even highlighting the differences. In spite of these differences many of the practices described in the report can be a starting point for improved water management as they may be adapted to the specific conditions of an individual site.

There is a general assumption that good water management is expressed by using the least possible water per unit of production. However, the amount, variety and quality of the water available are important factors. By definition, using more water will increase energy for transport, cleaning and recovery. The survey results show that water consumption, expressed as water intake, varies greatly between steelworks, from under 1m^3 to over 148m^3 per tonne of steel.

Average water consumption and discharge per tonne of steel, on the other hand, are close to each other, 28.4 and 25.4 m^3/tonne respectively. This indicates an overall efficient use of water, as few losses appear to be occurring in the processes. In most cases the loss is due to evaporation.

The quality of the management approach to water should therefore not be assessed based on only water consumption per tonne of steel produced.

Water is used mainly for once-through cooling (over 81% in relation to total intake), especially at integrated steelworks. Significant differences can be observed between plants using once-through cooling and circulation cooling. The choice of technique is mainly due to the location of the plant. In general, seawater is the preferred option for once-through cooling due availabilty and costs.

In this report, a distinction has been made between the two main steel production routes; the integrated route and the electric arc furnace route. For the integrated route, 17 plants contributed data, and the average consumption and discharge are 28.6 m^3/tonne of steel and 25.3 m^3/tonne of steel respectively. Eight participants produce steel via the EAF route and their average consumption and discharge are 28.1 m^3/tonne of steel and 26.5m^3/tonne of steel respectively.

Analysis shows that blast furnace processes are the biggest water consumers in the steel industry followed in order of importance by hot rolling, cold rolling and cokemaking. Still, significant differences can be seen between similar processes at different plants because of water availability, legislation, plant configuration and so on. In assessing these numbers it is important to note that the water use is expressed in m^3/tonne of specific product and not in m^3/tonne of steel.

The water management matrix is a useful tool for the self assessment of an organisation's water management efforts across the company. It covers nine areas including: Policy, Water Management and Organisation and Water Metering. The matrix can be used by companies that wish to improve their performance in water-related matters.

As part of the survey, respondants assessed the water management efforts of their steelworks on a scale of 0 to 4, which were converted into percentages for the results.

Responding steelworks rated their water management efforts to be an average 67% across the matrix. The lowest score was 31% and the highest score was 94%. The lowest overall score for specific sections of the survey was in Procurement (61%) and the highest was in Maintenance and Future Investment Plans (both 72%).

The participants rated their water management efforts rather high, which could be an indication that those companies are more active in their water management than the industry in general. The results might not directly reflect the efforts of the entire steel industy.

Data on the techniques applied as well as discharge water quality were collected and are available in a digital database. The availability of water, the type of water available and legislation also determine the used pre- and post-treatment techniques. Therefore, there are no simple conclusions about best available techniques.

There are several ways in which water management practices within the steel industry can improved as a result of this project. The water management survey is useful for any plant in the industry. It gives a good overview of water management on a steelmaking site. The results of the data collected can be used to compare sites with similar configurations, to stimulate improvement projects and perhaps cooperation between sites. In addition, the case studies provided by several participants helps to share good practices and provide solutions.

Recommendations

The benefits of this project for the global steel industry can be enhanced if cooperation is continued. In particular, discussion among water experts within the industry can lead to faster implementation of proven good practices and the experts will benefit from having a network for problem-solving. In addition to that, the survey tool provides a simple means to asses water management within a plant or for a process.

In this context, the working group makes the following recommendations:

- Water flow diagrams provide a good overview of the flow of water within steel plants. It would be desirable to keep the diagrams up to date and, if possible, to add more.
- It is clear that "best practice" depends on local circumstances and cannot be generalised. However, to meet the future challenges in water management, applied technologies and practises need to be assessed further, completed with examples from additional plants and shared fully. The information gathered would then be a substantial and sound database for the iron and steel industry globally.
- The current water management matirx gives equal importance to all the different areas of water management. One improvement could be the development of a more complex matrix that incorporates importance multipliers for the various areas. This would lead to more meaningful and in-depth results.

As outlined in the introduction, the original scope of the project was more comprehensive than the final result. In future the following aspects should be explored further:

- legal issues such as limits on effluent quality and the role of legislation (eg. the EU's Water Framework Directive)
- the effects of specific (micro-)pollutants
- future availability of water
- specific considerations and recommendations for greenfield sites
- fact sheets, which would also be useful in policy discussions
- design aspects for water management for greenfield developments.

To take advantage of the network of water management experts established during the project, the working group suggests creating a water management expert network for communications on water issues. For the network and the exchange to remain active it will be necessary for the network to meet from time to time. The working group therefore suggests organising dedicated water management workshops for water management experts. The workshops could take the form of a conference where papers and solutions can be presented. Ideally, the workshops should be hosted by members at their sites to allow for plant visits.

Finally, the working group suggests regular data collection using the water survey for this project.

Appendix A: Case studies

Case studies: Coke plant wastewater treatment

1.1 China Steel Corporation

There are two main wastewater streams – the coke oven, and sanitary wastewater in the biological treatment plant. A combined series of treatments including aeration, clarification, filtration, ozone oxidation and active carbon adsorption processes have been successfully operating in the biological treatment plant since 1980.

Influent characteristics

Sanitary wastewater comes from the in-plant sewage system, so the wastewater has relatively low concentrations of chemical oxygen demand (COD) and oil. Coke oven wastewater comes from coal by-product distillation processes and contains high concentrations of organic compounds. Both wastewaters have biodegradable characteristics and are therefore treated in the biological treatment plant. The influent characteristics are shown in the table below.

	Flow	Temperature	COD	TKN	CN	TSS	Phenols
	m^3/h	°C	mg/l	mg/l	mg/l	mg/l	mg/l
Coke oven	120~150	30-38	4,000~6,000	800~1,500	5~30	10-50	600-1,000
Sanitary	120~150	20-35	150~650	200~300	-	50-200	-

Table 1.1.1 Composition of different wastewater flows at China Steel Corporation

Description of the biological treatment plant

Both influent wastewater streams are first equalised in a 4,000m^3 mixing basin. There is then a 40-50% COD removal, mainly phenolic compounds, by the pure oxygen aeration process which was set up for increasing the ability of COD reduction in 2006. Then the residual COD is removed by a second aeration process (mainly sulphide and cyanide compounds) by surface aerators. The aerators are controlled by measuring dissolved oxygen continuously and comparing it with a set point of 1.5 to 5 mg/l. Also, pH is controlled by adding caustic soda when the pH is lower than 6.8.

After clarifying in the slurry settling basin, the wastewater is filtered through sand. An ozone oxidation system (set up in 2005) oxidises the non-biodegradable residual COD, which is around 30% of the COD present in the raw wastewater.

After this process, the active carbon adsorption process reduces the colour of the wastewater. Finally, the wastewater is discharged together with the other wastewater streams to the sea. Excess slurry is pumped to a thickener first. The sludge is then dewatered and incinerated.

Dimensions of the plant

The pure oxygen aeration tank volume is 2,000m^3 and the active sludge aeration basin volume is 9,500m^3. This means a hydraulic retention time of 31 hours.

The second clarifier volume is 1,960m^3 with a 25m diameter and 10~20m^3/m^2/d surface loading. The sludge thickener is a basin with a diameter of 22m and a volume of 1,150m^3. Average sludge discharging rate is 25m^3/day with 3% dry solid. The slurry recirculation flow is 320m^3/h. There are three sand filters present for removal of suspended solids after the second clarifier basin.

The ozone system produces 36kg/h with 120ppm ozone dosage and there are three granular active carbon adsorption columns with each 100m^3 granular active carbon filling.

The biological wastewater treatment procedure is shown in the figure below. The following figure is a photograph showing an overview of the biological wastewater treatment plant.

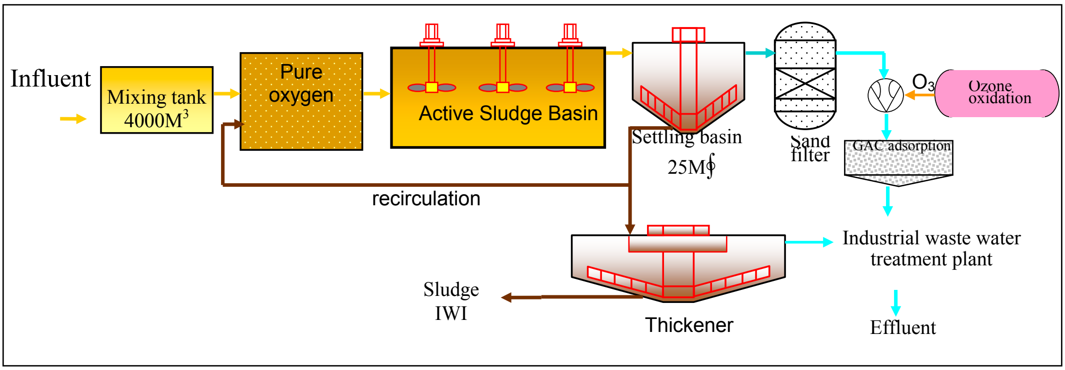


Figure 1.1.1 Flow of the new biological treatment plant

Figure 1.1.2 The biological treatment plant of China Steel

Effluent characteristics

The quality of the treated wastewater in 2009 can be seen in the table below, with the maximum permitted effluent values. Tests showed that the residual amount of COD was not biodegradable. So the overall efficiency of the plant for removal of COD is excellent, at around 90%.

		Average	Range	Effluent value permit
Flow	m^3/d	46.087	40,000~60,000	79.716
TSS	mg/l	11	5~20	30
COD	mg/l	55	45~90	100
Cyanide - total	mg/l	0,12	0,05~0,2	1,0
Cr	mg/l	0,01	<0,02	0,5
Cu	mg/l	0,009	<0,02	3,0
Pb	mg/l	0,01	<0,02	1,0
Zn	mg/l	0,091	<0,1	5,0
Cd	mg/l	0,00017	<0,002	0,03
Hg	mg/l	0,0005	<0,001	0,005
Fe	mg/l	0,39	<1	10
Oil	mg/l	3,3	2,0~6,0	10
Phenols	mg/l	0,05	<0,1	1,0

Table 1.1.2 Wastewater effluent quality

Because the treated water is discharged almost directly into the sea there are no strict limits for nitrate concentrations.

1.2 ArcelorMittal Tubarão

Wastewater treatment (WWT) at the ArcelorMittal Tubarão coke plant is mainly composed of activated sludge of extended aeration and continuous flow. Its aim is to reduce phenol concentration, COD (chemical oxygen demand), BOD (biochemical oxygen demand) and ammonia, which compose the liquor generated during the coking process. Other contaminants, such as cyanide, are also generated during the coking process and chemically treated before the biological reactor, forming a ferrous sulphate complex.

A nitrification process takes place in the WWT biological reactor, consisting of the oxidation of the organic nitrogen by the nitrifying bacteria, producing nitrite, nitrate and new cells. A high consumption of free oxygen and release of hydrogen ions are observed in this process, which leads to a reduction in pH and increase in alkalinity consumption.

The WWT does not have a denitrification process yet, as it is being implemented. It will consist of the reduction of the nitrate in the nitrogen gas generating savings of oxygen in the biological reactor and making the consumption of the hydrogen ions possible, recovering alkalinity. Denitrification will also eliminate biological sludge flotation, which currently happens in the secondary clarifier and improves the quality of the final effluent.

Effluent characteristics

Before reaching the WWT, the liquor from the coke batteries passes through two gravel filters for the removal of tar. After that, it goes to the stripping soda (the ammonia distillation column) to convert fixed ammonia into free ammonia from where it flows out together with steam to be burned in the combustion chamber.

After these processes, the liquor at the entrance of the WWT still has high concentrations of COD, phenols, ammonia and cyanide which will be submitted first to a chemical and then a biological treatment (see table below).

Parameters	Results
Outflow (m^3/h)	46
Temperature (°C)	< 37
pH	7,3
BOD (mg O_2/l)	890
COD (mg O_2/l)	2.420
Total cyanide (mg/l)	3,0
Total phenols (mg/l)	410
Sulphide (mg/l)	6,2
Oils and grease (mg/l)	5,7
Ammonia Nitrogen (mg/l)	130
Total Phosphorus (mg/l)	1,1
Suspended solids (mg/l)	70
Total Zinc (mg/l)	0,14
Total Lead (mg/l)	0,01

Table 1.2.1 Composition of the liquor entering the coke plant wastewater treatment (2009)

Description of the coke plant wastewater treatment

The ArcelorMittal Tubarão WWT consists of two tanks, a clarifier, a biological reactor, a secondary clarifier, recirculation of activated sludge, a sludge thickener and a centrifuge.

The equalisation tanks receive the liquor from the ammonia distillation columns and their objective is to keep the flow as constant as possible at the entrance of the primary clarifier and the biological reactor.

At the primary clarifier the first treatment of the liquor occurs, which is the chemical removal of cyanide with the addition of ferrous sulphate, forming a ferrocyanide complex also called chemical sludge, of lime for pH correction and polymer for ferrocyanide precipitation. The control items monitored are: liquor temperature <37˚C, total cyanide after primary clarifier <1.3mg/l and pH between 7.5 and 8.0.

The second step of the treatment takes place in the biological reactor. It includes the removal of COD, phenols and ammonia through aerobic metabolism carried out by the microorganisms (bacteria and protozoa). The reactor has six aerators (two surface and two depth)and the dissolved oxygen intended is >1.0mg/l. The pH is controlled at between 6.8 and 7.2 by the addition of lime.

Phosphoric acid is added as nutrient for the microorganisms and is controlled at values >1.0mg/l of total phosphorus in the final effluent. Microbiological analysis are carried out once a week to control nitrifying bacteria and protozoa population as well as identify possible impacts caused by operational instability in the previous processes.

The decantation of the biological sludge occurs in the secondary clarifier. Every day, part of the sludge is discarded into a thickener tank according to the age of the sludge.

Another part returns to the biological reactor keeping the activated sludge process going. The chemical sludge from the primary clarifier is also pumped into the thickener tank every day. Both types of sludge go to the centrifuge where they will be discarded with the use of a cationic polymer. After centrifugation (70% of moisture) it goes to the sinter plant.

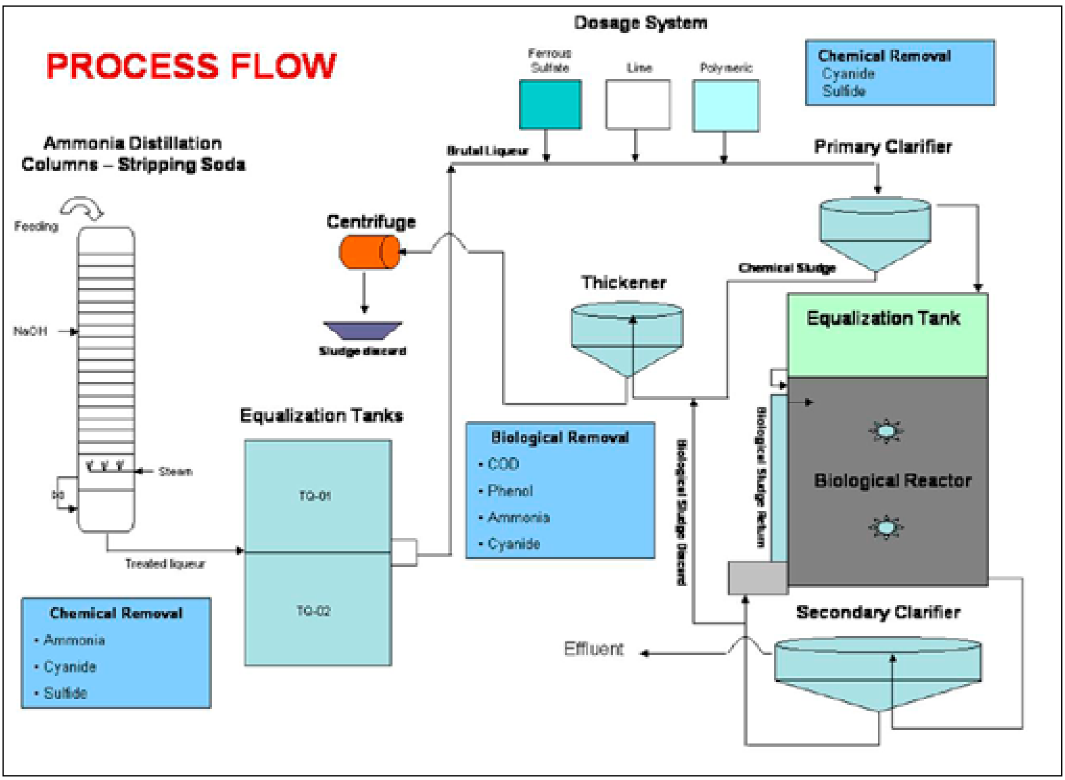


Figure 1.2.1 ArcelorMittal Tubarão coke plant wastewater treatment flow

Figure 1.2.2 Overview of ArcelorMittal Tubarão coke plant wastewater treatment

Coke plant wastewater treatment dimensions

Equalisation tanks (total of 2 tanks):	1,200m^3
Primary clarifier:	280m^3
Biological reactor:	5,160m^3
Secondary clarifier:	704m^3
Sludge thickener tank:	109m^3
Age of the sludge:	50 days
Recirculation outflow of the biological sludge to the reactor:	200m^3/h
Biological sludge average discard outflow:	40m^3/day

Effluent characteristics

The treated effluent is discarded directly into the sea. The quality of the effluent and the limits established by Brazilian legislation are described in the table below.

It is important to note that the WWT has had a stable operational process since 2003 with no occurrence of results above the established limits.

Parameters	Results	Legal limits
Outflow (m^3/h)	102	-
Temperature (°C)	28	<40
pH	7.6	5.0 – 9.0
BOD (mg O_2/l)	2.3	-
COD (mg O_2/l)	82	200
Total cyanide (mg/l)	0.13	1.0
Total phenols (mg/l)	0.013	0.5
Sulphide (mg/l)	<1.0	1.0
Oils and grease (mg/l)	4,9	-
Total phosphorus (mg/l)	0.92	-
Suspended solids (mg/l)	31	100
Ammonia Nitrogen (mg/l)	1.5	20
Total zinc (mg/l)	0.01	5.0
Total lead (mg/l)	0.009	0.5
Total mercury (mg/l)	0.001	0.01
Dissolved manganese (mg/l)	0.04	1.0
Fluoride total (mg/l)	4.8	10.0
Total chromium (mg/l)	<0.010	1.0
Total cadmium (mg/l)	<0.005	0.2
Total arsenic (mg/l)	0.005	0.5
Dissolved copper (mg/l)	<0.005	1.0
Total copper (mg/l)	<0.005	1.0
Total aluminium (mg/l)	0.04	-

Table 1.2.2 Composition of the effluent of the coke plant wastewater treatment and the permitted limits for release into the environment (2009)

1.3 Tata Steel IJmuiden

Combined treatment of four wastewater flows in a biological treatment plant according to the pre-DN/N concept where pre-DN/N stands for pre-denitrification-nitrification, has been successfully in operation since 2000.

Nitrification and COD removal takes place simultaneously in the aerobic part of the installation. The end products from this conversion are CO_2, water and nitrate, NO_3.

Denitrification is the biological process where nitrate is converted by bacteria into nitrogen gas. This process happens under anaerobic or anoxic conditions, so there needs to be a special part of the installation where dissolved oxygen concentrations are more or less equal to zero. Denitrifying bacteria also some COD as feed. By putting (part of) the influent in the anoxic part of the installation and recycling nitrified wastewater, COD and nitrate come together. As the denitrification takes place in the first part of the installation, this is called pre-denitrification.

Influent characteristics

Water from the gas scrubbers at the blast furnaces contains relatively high amounts of zinc and other metals, cyanide, COD and TKN. After removing the metals by sulphide precipitation (adding of Na-sulfide) and settling, the water can be treated with biological processes.

The same goes for water from the sinter plant scrubbers. By varying pH the different metals present in the gas scrubber water will settle. Then the COD and TKN left in the water can be removed in the biological treatment plant (see table below).

At our oldest coke plant, severe contamination of the groundwater was found. Experiments showed that the BTX present in this water can be biodegraded very well. So this water is also sent to the biological treatment plant.

	Flow	Temp	COD	TKN	CN-total	TSS	Zn	Metals	Phenols	CNS
	M^3/h	°C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
BF	140-150	40-44	65-120	130-150	5-20	25-35	2-4	1-3	-	-
SP	50-55	35-40	250-450	200-300	-	10-25	-	0.3-0.5	-	-
CP	80-90	30-35	3,000-3,500	200-300	20-60	20-50	-	-	500-750	200-250
GW	35-40	10-12	150-350	100-200	10-20	<10	-	-	-	-
Total	320	33	1,100	180	15	25				

BF = Blast furnace scrubber water blow down
SP = Sinter plant scrubber water
CP = Coke plant effluent
GW = Polluted groundwater form CP #1

Table 1.3.1 Composition of the different wastewater flows

Description of the biological treatment plant

The heart of the new water treatment configuration at Tata Steel IJmuiden is the biological treatment plant, a carrousel type of installation that was built in 1999–2000. Carrousels are well known in Western Europe where they are often used for the treatment of domestic wastewater.

The large basins with surface aerators and the relatively high velocities make the installation more a complete mix reactor than a plug flow. The aerators are controlled by measuring dissolved oxygen continuously and comparing it with a set point of 1.5 to 2mg/l. Also, pH is controlled by adding caustic soda when the pH is lower than 6.8 or by adding sulphuric acid when the pH in the basin is higher than 7.4.

Continuous backwashing sand filters were installed behind the biological effluent treatment plant. Despite the fact that the combination of wastewaters can easily be treated, sometimes very fine biological flocks are present in the overflow of the final settling basin. Excess sludge is pumped to a thickener first. The sludge is then dewatered and mixed with the coal that is used as input for the ovens.

The photograph below shows the carrousel with the surface aerators installed in the blue boxes. These boxes are isolated to prevent problems with noise in the direct neighbourhood of the installation. The light blue columns in the foreground are the six sand filters; towards the back are the blast furnaces no. 6 and 7.

Figure 1.3.1 The new biological treatment plant

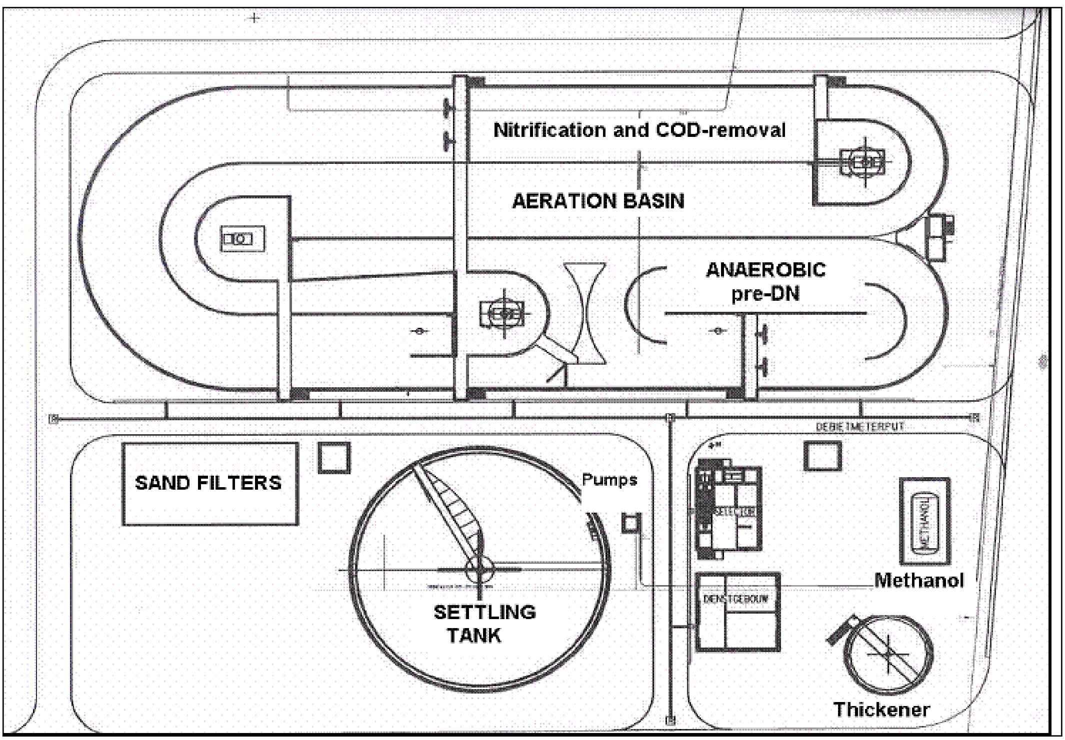


Figure 1.3.2 Floor plan of the new biological treatment plant

Dimensions of the plant

The aeration volume is 15,000m^3. This means a hydraulic retention time of 33 hours. The settling volume is 1,500m^3. The diameter of the settling basin is 29m. The surface load is 5m^3/m^2/h.

The sludge thickener is a basin with a diameter of 9.5m and a volume of 250m^3. Average sludge waste is 45m^3/day with 3% dry solids. The sludge recirculation flow is max 640m^3/h (twice the amount of influent). Dosage of phosphoric acid is based on 2mg/l phosphate in effluent. That means approximately 5l/h 75% phosphoric acid has to be added.

Effluent characteristics

The quality of the treated wastewater in 2007 can be seen in the table below. Tests showed that the residual amount of COD (appr. 100mg/l) is not biodegradable. So the overall efficiency of the plant concerning the removal of COD is excellent.

The denitrification part of the plant is not functioning as expected. Probably the cyanide present in the wastewater is inhibiting or preventing the growth of denitrifying bacteria. As a result the nitrate concentrations in the treated wastewater are 250mg/l or higher.

TKN conversion to nitrate is almost complete, so the nitrification part of the installation is working very well.

		Average	Range
Flow	m^3/h	280	180 – 350
TSS	mg/l	30	3 – 110
COD	mg/l	100	80 – 160
TKN	mg/l	6	2 – 15
Phosphate	mg/l	2,4	0.8 – 7
Cyanide-total	mg/l	5	2 – 9
Cyanide-free	µg/l	90	19 – 375
Thiocyanate	mg/l	1.7	0.4 – 4.9
Cr	mg/l	0.013	0.011 – 0.015
Cu	mg/l	0.018	0.015 – 0.028
Pb	mg/l	0.166	0.041 – 0.380
Ni	mg/l	0.020	0.010 – 0.061
Zn	mg/l	0.125	0.051 – 0.262
Cd	µg/l	14	6 – 32
Hg	µg/l	0.5	0.2 – 1.0
As	µg/l	13	6 – 19
Phenols	mg/l	<0.15	–
PAH	mg/l	0.0013	0.0003 – 0.0045

Table 1.3.2 Wastewater discharge quality (2007)

In the last table, below, the limits set by the discharge permit are shown. As the treated water is discharged almost directly into the sea there are no strict limits for nitrate concentrations.

		Average	Maximum
Flow	m^3/h		350
TSS	mg/l	60	80
COD	mg/l	135	150
TKN	mg/l	15	30
Phosphate	mg/l	5	10
Cyanide-total	mg/l	10	15
Cyanide-free	µg/l	0.35	0.45
Thiocyanate	mg/l	2	4
Cd	µg/l		10
Hg	µg/l		5
As	µg/l		25
Cr+Cu+Pb+Ni+Zn	mg/l		0.8
PAH	mg/l		0.005

Table 1.3.3 Limited values from discharge permit

1.4 voestalpine Stahl

voestalpine Stahl operates its own coking plant in Linz with an annual production capacity of roughly 1.9 million tonnes of coke. Approximately 1.4 million tonnes of coke is produced annually in five batteries, each of which consists of 40 coke ovens.

Description of the line and operating procedures

The production facility essentially consists of two parts, called the white side and the black side. The coke is produced on the black side. The coking plant incorporates the following process steps:

- supply, milling and storage of the coal grades/mixing/storage of the coal charging mixture
- recovery of the oven content with coal cars on the oven roof
- opening of the charging holes on the oven roof of the oven to be filled
- filling of coal into a single coking oven
- airtight closure of the oven
- coking (heating, degasification, coke formation)
- opening of the coke door and machine door on the machine side
- extraction process
- coke quenching.

Physical and chemical processes are carried out on the white side, the coal by-product section of the coking plant, in order to generate by-products and clean constituents from the crude gas. The following process steps are relevant:

- gas cooling
- tar recovery from the coke oven gas
- desulfurisation of the coke oven gas
- ammonia recovery from the coke oven gas
- crude benzene recovery from the coke oven gas
- H_2SO_4 production.

Types of wastewater

The following types of wastewater occur during the coking process:

- cooling water, once-through cooling, with drainage into the Danube river
- process water, drainage into the municipal treatment plant for final biological cleaning.

Cooling water, once-trough cooling

Cooling water is needed to lower the temperature of the crude gas, which is accomplished by channeling the gas through a cross-tube cooler. Cooling systems are also required for process-related material flows. Circuit water is also used in these systems as the cooling utility. The water is returned into the Danube completely clean and only heated as a result of the cleaning process.

The once-through cooling system at voestalpine in Linz was chosen for its location on the outskirts of the city. The use of once-through cooling instead of cooling towers ensures that no water vapour can escape during the winter and cause industrial snow and icy streets. The once-through cooling system is only possible because the Danube has a sufficient amount of water flow volume. The temperature of the water as it is drained into the river is documented by an immission-based temperature monitoring software program.

Process water

After being chemically and physically pre-cleaned in the integrated metallurgical facility, the process water from the coking plant is piped to the large-scale municipal treatment plant that is equipped with nitrification and denitrification steps in the biological final cleaning system. The wastewater is primarily accumulated in two different plant sections.

Gas cleaning system

Before the coke oven gas is used, it is cleaned in a series of steps. The wastewater from the coking plant contains coke plant-specific compounds. The wastewater is circulated where possible, pre-cleaned through pH level increase and vacuum treatment and subsequently introduced to the large-scale treatment plant.

Condensate

Wastewater occurring as a result of coal dampness is collected and pre-cleaned. First, the tar is removed from the water. Ammonia, hydrogen cyanide, hydrogen sulfide and carbon dioxide are separated in a further step in a combined dryer-deacidifier unit. Then the water is biologically cleaned in a final step in the large-scale treatment plant.

To ensure environmental compatibility, a software program regularly measures the water drained into the river as it leaves the treatment plant at the integrated metallurgical facility.

Case study: Blast furnace cooling and gas cleaning

2.1 Oyak Isdemir

Blast furnace cooling

Blast furnace cooling with separate closed cooling circuits normally works with a water inlet temperature of about 40°C. Demineralised water is used for these closed-loop cooling circuits to protect the cooling elements from clogging and from corrosion caused by calcium deposits. The circuits are pressurised with nitrogen to optimise the working pressure and to avoid contact with oxygen from the ambient air.

Isdemir's blast furnace is cooled by three individual closed-loop cooling circuits, operated by demineralised cooling water and pressurised by nitrogen. Each circuit is connected to the existing emergency network and the existing make-up water network. The emergency and make-up water circuits are common for the three closed loop cooling circuits. The water flow diagram is shown in the figure below.

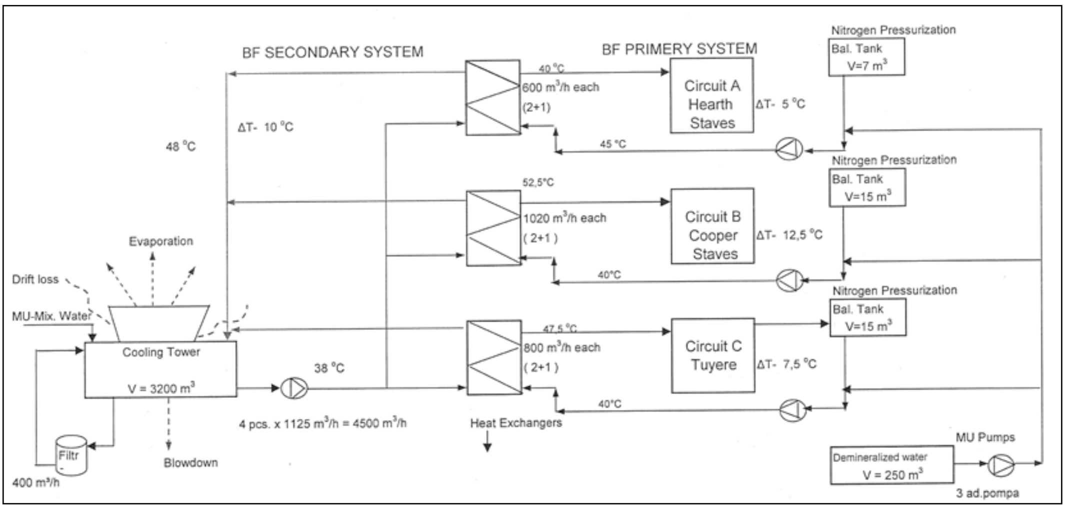


Figure 2.1.1: Cooling water flow diagram of Isdemir blast furnace (BF)

Circuit A

Low pressure circuit (3 bars) for the hearth staves, the tap hole staves, the tuyere ring staves and the under hearth (bottom) cooling. Low pressure means that the water pressure inside the cooling channels of the cooling elements is lower than the gas pressure at the same level inside the blast furnace. In case of leakage, blast furnace gas will enter into the cooling elements. No water will enter the blast furnace in case of leakage. This is to minimise explosion risks.

Circuit B

Medium pressure (7 bars) circuit for the bosh, belly, stack and throat armour staves as well as three probes. Medium pressure means that the water pressure inside the cooling channels of the cooling elements is higher than the gas pressure at the same level inside the blast furnace. In case of leakage, blast furnace gas will not enter into the cooling elements. Water will enter the blast furnace in case of leakage. This is to avoid blast furnace gas in the closed-loop cooling circuit, damaging other cooling elements in serial due to the lack of cooling water.

Circuit C

High pressure (10 bars) circuit for the tuyere noses with the tuyere bodies in serial, for the tuyere coolers and for the hot blast valves. High pressure means that the water pressure inside the cooling channels of the cooling elements is much higher than the gas pressure at the same level inside the blast furnace. In case of leakage, blast furnace gas will not enter the cooling elements. Water will enter the blast furnace in case of leakage. The high pressure is necessary partly because of the pressure drops of the cooling elements and cooling elements in serial. It also brings the evaporation point of the cooling water to a higher level.

Blast furnace gas cleaning system

The system that cleans the blast furnace gas uses 3,300m^3/h of water for the gas cleaning scrubbers and 400m^3/h of water for the electro filter.

Water contaminated with particles after gas cleaning is transported to radial thickeners where the particles will settle by gravitational force. After precipitation, sludge is pumped to the sinter plant. After settling the water goes goes to a concrete tank and is then pumped to the cooling towers to cool and reuse the water. From the cooling towers the water is stored in another tank and then pumped to the gas cleaning scrubbers and electro filter.

Remarks

In general, at the facilities of Isdemir, water is mainly used for cooling and gas cleaning. Seawater systems are included here. They should be considered seperately from the other systems because seawater is used for once-through cooling and there is no treatment, precipitation or any other process applied. The amounts of seawater used are huge.

Case study: Pellet plant gas cleaning

3.1 Tata Steel IJmuiden

During the pelletising process approximately 1,000,000Nm³/h of flue gas is produced. To minimise the emission of fluoride, six similar gas scrubbers are installed. By circulating water over the scrubbers and to neutralise the circulation water by adding caustic soda, more components (except fluoride also SO_2) are removed from the gas.

Because a part of the water is evaporating, the solids and salt concentration in the circulating water could rise to unacceptable levels if the system had no blowdown. From the circulating 3,000m³/h a part i.e. 500m³/h is lead to the settling basin to remove the solids (see figure below).

From this settling basin 450m³/h is pumped back into the circulating water flow. The rest is extracted from the water system and further treated in the arsenic removal plant. Sludge is dewatered in a filter press.

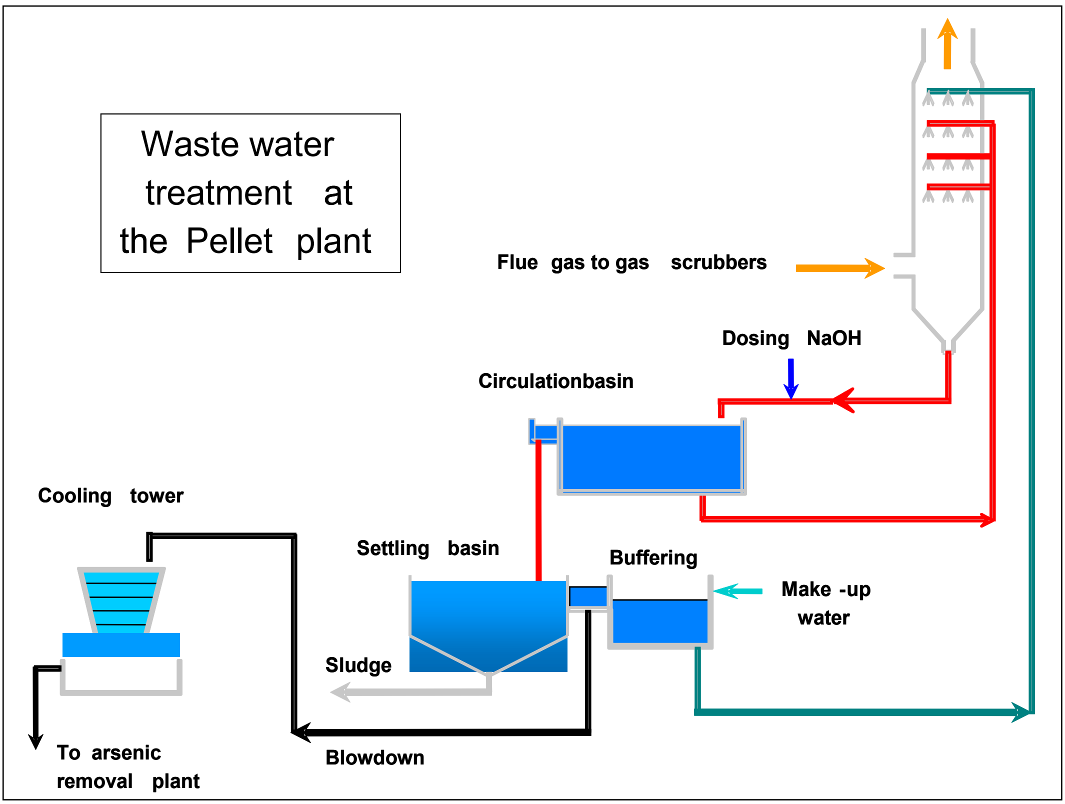


Figure 3.1.1 Water treatment at the pellet plant

Water quality

The composition of the water going to the arsenic removal plant is described in the table below.

		Average	Minimum	Maximum
Flow	m^3/d			
TSS	mg/l	160	2	2,300
COD	mg/l	75	3	320
TKN	mg/l	16.9	1.1	98
Cd	mg/l	0.019	<0.001	0.110
Hg	mg/l	0.053	<0.0001	13.7
As	mg/l	1.3	0.03	8.2
Cr	mg/l	0.03	0.007	0.20
Cu	mg/l	0.03	0.003	1.4
Ni	mg/l	0.160	0.02	0.98
Pb	mg/l	0.03	<0.03	0.2
Zn	mg/l	0.175	0.02	5.65

Table 3.1.1 Composition of influent at the arsenic removal plant

Case study: Sinter plant

4.1 voestalpine Stahl

voestalpine operates a sintering line in Linz. The maximised emission reduction of sintering (MEROS) offgas cleaning system was put into operation in August 2007. The filter system is made of fabric and works with injection of additives. MEROS is unique and has redefined the state of art in offgas cleaning. This technology replaces wet-type offgas cleaning.

Description of the line and operating procedures

The main task of the sintering plant is the production of a blast furnace burden containing high concentrations of iron. The sintering process involves homogenisation of ore fines, recycled metallurgical materials and other additives in mixing beds and then adding combustibles. The grains of ore melt at a temperature of roughly 1,300°C, and the entire mixture becomes a porous sinter cake. After it is cooled, the sinter cake is broken into smaller lumps and transported on conveyor belts directly to the blast furnace.

The MEROS offgas cleaning system

The original AIRFINE offgas cleaning system (wet-type filter) was replaced by a MEROS dry offgas cleaning system. Coarse dust is removed from the offgas emitted from the cleaning process using electric filters and subsequently channeled into a gas conditioning system. There, volatile heavy metals such as mercury and organic compounds are bound through the injection of calcium hydrate, sulfur dioxide and other acidic gases and by adding hearth furnace coke.

Temperatures are monitored to ensure that water is injected at the correct rate and to ensure proper gas conditioning to optimise the adsorption process. The water introduced into the process evaporates. The downstream fabric filter separates dust and other adsorbed materials. Dust is returned in a portion of the stream, which is discharged to achieve more effective use of the adsorbed materials.

Types of wastewater

The following types of wastewater occur during the sintering process: cooling water, once-through cooling, with drainage into the Danube river.

Cooling water, once-through cooling

Cooling water is needed to cool the offgas exhaust system, a series of heat exchangers for air-conditioning systems for the maintenance and transformer rooms. The water is returned into the Danube completely clean and only heated.

The once-through cooling system at voestalpine in Linz was chosen for its location on the outskirts of the city. The use of once-through cooling instead of cooling towers ensures that no water vapour can escape during the winter and cause industrial snow and icy streets.

The once-through cooling system is only possible because the Danube has a sufficient amount of water flow volume. The temperature of the water as it is drained into the river is documented by an immission-based temperature monitoring software program.

Figure 4.1.1 voestalpine Stahl, Sinter plant

Figure 4.1.2 voestalpine Stahl, MEROS offgas cleaning system

Case studies: Basic oxygen steelmaking and casting

5.1 Bluescope - Port Kembla Steelworks

Freshwater supplied to the steelworks is a blend of around 35% municipal drinking water supply (direct from dams) and 65% recycled effluent from an adjacent municipal sewage treatment plant. Numerous internal recycle streams are used.

The Slabmaking Department produces approximately 5.3 tonnes of steel slabs annually. It consists of the basic oxygen steelmaking (BOS), steel treatment, slab caster, slab handling, slab yard and a lime kiln plant.

Water use

A large proportion of the freshwater used in slabmaking is first used in the slabcasting section. It recirculates in succession through some three to five circuits (moulds and machines, continuous casting machine sprays, vacuum de-gassing, scarfer and slab cooler), being progressively blown down through the system to maintain the desired concentration of dissolved solids in each stage.

It is then blown down to the BOS section where it re-circulates through another three to four cooling and dust collection circuits (hood cooling, misc. water, secondary dust collection and primary dust collection).

The final discharge, which serves as a blowdown for the department as a whole, is then used to convey solids collected from the dust collection system to an on-site treatment facility which dewaters the solids and treats and discharges the remaining wastewater to drain. This is the only liquid process discharge from the department.

The BOS also requires make-up water and receives as much as practicable of the blowdown water from the hot strip mill (HSM) for reuse. However, this is suited only for use in the dirtier circuits (miscellaneous and dust collection water) because of the high dissolved solids content of the HSM blowdown. The BOS also requires some additional industrial water for make-up.

Comprehensive water treatment and water quality analyses minimise blowdowns and maximise cycles of concentration at each step in the sequence. Operational and maintenance problems such as scaling and/or chloride corrosion are experienced as a result of the high level of recycling.

The water balance of slab casting is presented in the flowchart below.

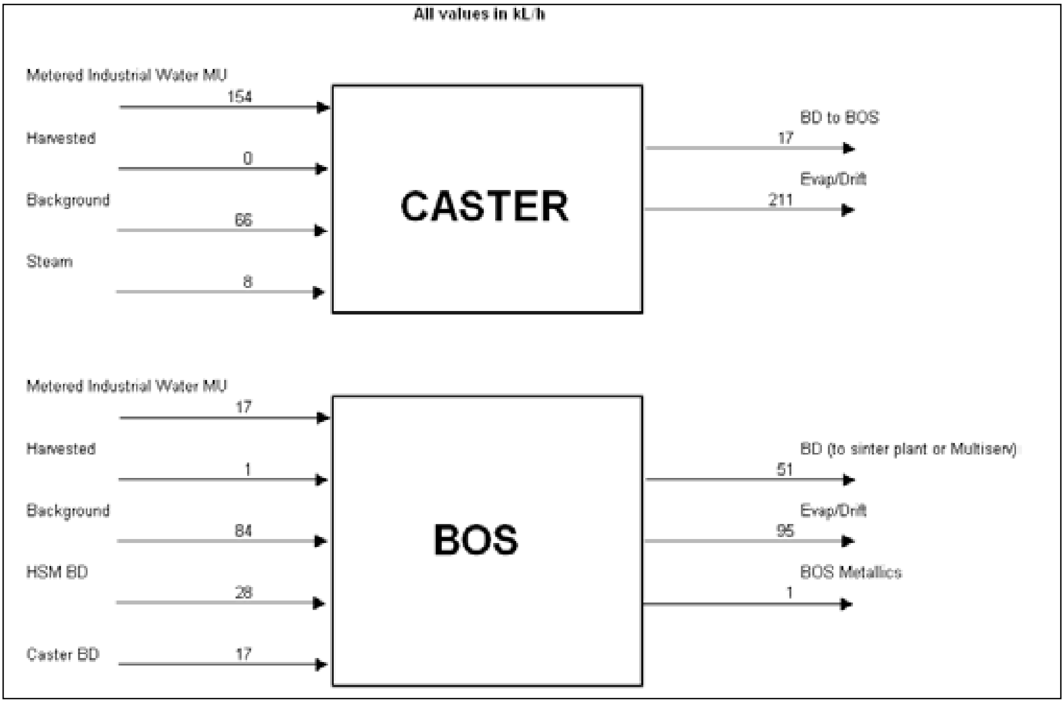


Figure 5.1.1 Macro water balance for slabmaking

Methods for pre- and/or post-treatment of the water

No pre-treatment of influent water is necessary in slabmaking (noting that the hot strip mill blowdown that is reused at the BOS is fed into systems that can handle the lower quality of this water rather than pre-treating it). Post-treatment of BOS blowdown water is done via an on-site treatment plant away from the slabmaking plant. It dewaters solids from the BOS slurry. The remaining wastewater is blended with other wastewaters, pH adjusted then discharged to a licensed drain.

Quality of treated water

Wastewater from the steelmaking process is blended with wastewater from blast furnaces, so this information is not available. BlueScope is investigating the potential to treat water extracted from the BOS blowdown slurry to a standard for reuse on-site.

Chemicals used and waste production

pH adjustment is undertaken on wastewater. Due to recirculation through cooling towers in slabmaking, sodium hypochlorite is used as a biocidal agent. A proprietary chemical treatment is applied to remove solids.

5.2 Třinecké Železárny

The basic oxygen furnace (BOF) steel plant has two converters with a capacity of 2.6 million tonnes a year, secondary metallurgy facilities (ladle furnace, vacuum degassing station), continuous casting machines and gas cleaning station. The BOF steel plant has an independent water treatment system, i.e. a system of water recirculation in closed water circuits.

Description of BOF water treatment

Water treatment of the BOF, which includes sludge treatment, uses these closed water circuits:

- cooling water circuit of BOF facilities and secondary metallurgy (indirect cooling) – cooling of converters, oxygen lances, ladle furnace, vacuum degassing station, etc.
- cooling water circuit of continuous casting machines (indirect cooling) – cooling of continuous casters and crystallisers
- secondary cooling water circuit of continuous casting machines (direct cooling) – cooling of blooms, rolls, stands, table rollers, burners of flame cutting machines, etc.
- water circuit of gas cleaning station – cooling and dedusting of steel-making gases from converters.

Water treatment involves cooling and treatment of reverse water in circuits, water recirculation and circuit refilling with incoming water. Water for circuit refilling is taken from surface water sources. The input water is put through sand filters as a pre-treatment. The input water for the water circuit of the gas cleaning station is not treated.

Water treatment in indirect cooling circuits involves water cooling in cooling towers and chemical preparation dosing to ensure circuit stabilisation (hardness stabilisers and corrosion inhibitors by the NALCO company).

Water treatment in the secondary cooling water circuit of continuous casting machines (direct cooling) before reuse involves treatment in vertical sedimentation tank (hydrocyclone), through sand filters, cooling in water-cooling towers and subsequently chemical preparation dosing for ensuring of circuit stabilisation (hardness stabilisers and corrosion inhibitors).

Water treatment in the circuit of a gas cleaning station before reuse involves treatment in pre-sedimentation tanks, in radial sedimentation tanks type DORR and cooling in water cooling towers. For pH correction and water hardness reduction gaseous CO_2 ($CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$) and hardness stabilisers are dosed.

The sludge from sedimentation tanks and filters is processed by a chamber filter press and reused.

Wastewater from BOF water treatment is drained through the sewerage system into an enterprise wastewater treatment plant for effluent polishing.

In the enterprise wastewater treatment plant, sedimentation of total suspended solids (TSS) in the sedimentation tank and separation of oily substances from water level are carried out.

Wastewater quality from BOF	
	Average
Temperature °C	28
pH	9.96
TSS mg/l	22
dissolved solids mg/l	2.098
ammonia mg/l	0.14
COD mg/l	22
total phosphorus mg/l	0.6
oil mg/l	<0.10
calcium mg/l	39
magnesium mg/l	8.2
iron mg/l	3.84
chloride mg/l	410

Table 5.2.1 Water quality from BOF after treatment

Figure 5.2.1 BOF water treatment system cooling towers

5.3 Oyak Isdemir

Slab casting water treatment plant

All the cooling water for the continuous caster is driven in three different systems, described below. The water from the individual stations have different qualities (heat loaded or scale loaded) and undergo treatment processes, for example scale pit, filters, heat exchangers and cooling towers. In this way the water can be cleaned and cooled, ready for reuse.

System 1: Closed circuit

- cooling water with a flow temperature of max. 50˚C, part-stream filtration, heat exchangers
- emergency cooling circuit.

System 2: Closed circuit

- cooling water with a flow temperature of max. 60˚C, part-stream filtration, heat exchangers
- emergency cooling circuit.

Semi-closed circuit

- cooling water with a flow temperature of max. 49.5˚C, part stream filtration, cooling towers
- emergency cooling circuit.

System 3: Open circuit

- spray cooling
- cooling water with a flow temperature of 50˚C, cooling
- water clarification by scale pit, filtration, cooling by cooling towers
- emergency cooling circuit.

The individual cooling circuits work with separate pump groups. Each pump group has at least one reserve pump that can start automatically. System 1 and System 2 are cooled by a water-water-heat exchanger. The cooling medium is treated water from the recooling system. The conditioning of the cooling circuits is done via dosing stations using corrosion inhibitors and biocides.

For system 3, the spray water loaded with finest scale flows from the scale pit through gravel filters and heat cooling towers to the cold well. Oils and fats on the surface in the scale pit are precipitated by an oil skimmer and transported to a tank. The separated water flows back into the scale pit.

The backwash water of the gravel filters is transported to the backwash buffer basin and is pumped to the scale plant.

The quantity of make up water consits of:

System 1	Mould cooling	approx. 1m³/h
System 2	Machine cooling	approx. 1m³/h
System 2	Open cooling	approx. 227m³/h
System 3	Spray cooling	approx. 108m³/h

In case of power failure, the emergency water valves at the emergency water tank and the valve at the outlet lines of the closed cooling circuits open automatically.

At the continuous casting machine the closed circuits and the spray cooling are supplied with emergency water in case of need.

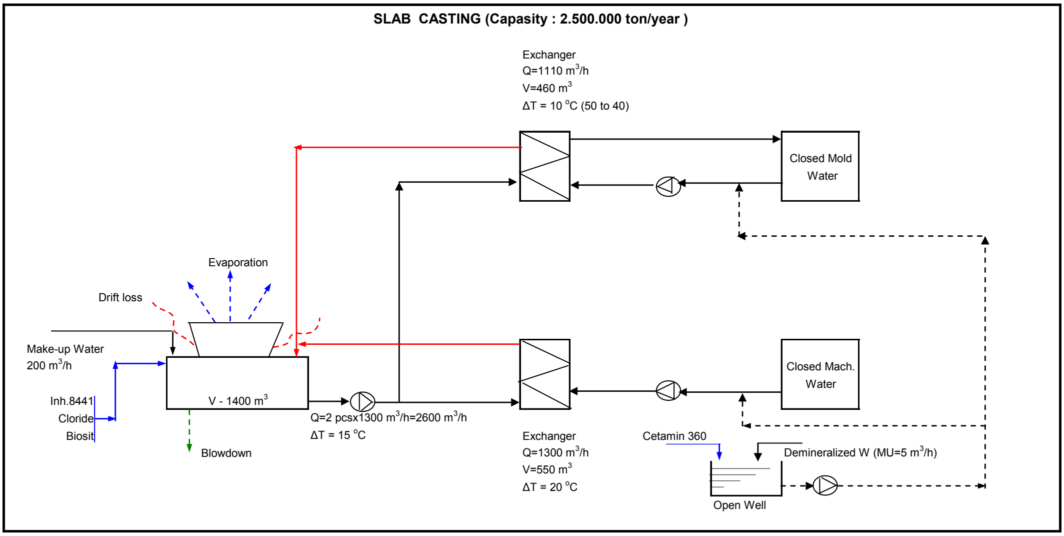


Figure 5.3.1 Flow diagram: Slab casting water treatment

Case studies: Hot-rolling mill

6.1 BlueScope – Port Kembla Steelworks

The Port Kembla hot strip mill (HSM) produces 3.2 million tonnes of hot-rolled coil a year. The HSM includes a hot coil processing and dispatch facility and a roll shop. It produces hot-rolled coil for internal, domestic and overseas customers. A hot-rolled plate mill is also operated on site with a capacity of 400kT to 450kT.

Most of the water use at the HSM goes to evaporation and blowdown losses from the recirculated cooling water system.

Description of the processes and treatment methods applied

The HSM uses both freshwater and excess plate mill process water. Of this, a large proportion evaporates through cooling towers (especially in summer) and the rest goes as blowdown, either to drain or to the BOS (both are metered) to control recirculated cooling water chlorides to acceptable levels. There are a significant amount of once-through industrial freshwater users, which are directed back to the recirculated cooling water system and are utilised as makeup for the system (called background water). A metered industrial water make up system is used to the settling pond when the conductivity gets high due to not enough dilution from the background water users.

The HSM has been receiving excess water from the plate mill ~10 m^3/hour (which is better quality than the HSM) rather than it going to drain, as this avoids unnecessary industrial water make up. Also, the HSM sends some of its blowdown to the BOS dust cleaning system, which requires lower quality water. Freshwater from the finishing mill oil cooler is recycled into the roll bite lubrication system rather than using an additional freshwater supply.

Excess blowdown that cannot be accepted at the BOS is discharged direct from the mill water circuit to a licensed drain. A key performance indicator is to minimise this discharge and to maximise reuse at the BOS (see figure below).

Amounts treated, removal efficiencies, capacities and design criteria

The mill water circuit is blown down to maintain <200mg/l chlorides (see table below).

Quality of treated water

Recirculated mill water has the following analysis:

Temp.	TSS	Turb	BOD_5	COD	MBAS	Cu	Ni	NO_2	NO_3
°C	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
25.8	5.2	14.5	6	43	0.16	0.00	0.00	0.80	0.55

Table 6.1.1 Analysis of the recirculated mill wate

Chemicals used in waste management

Ferric chloride assists in removal of oils, sodium hypochlorite as a biocide and pH level is controlled with caustic.

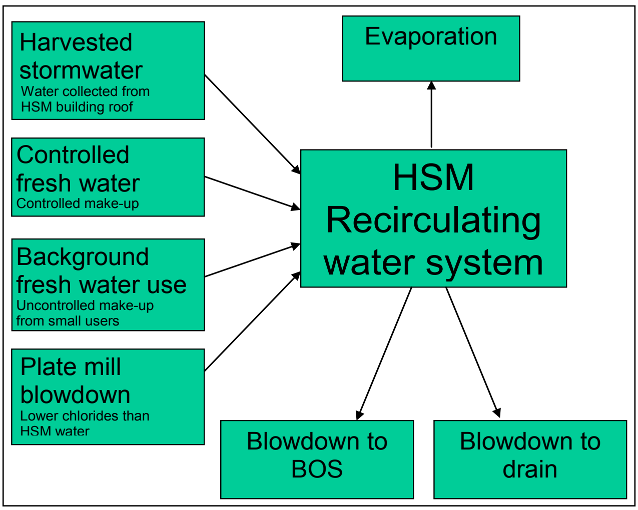


Figure 6.1.1 Simplified flow diagram HSM BlueScope – Port Kembla Steelworks

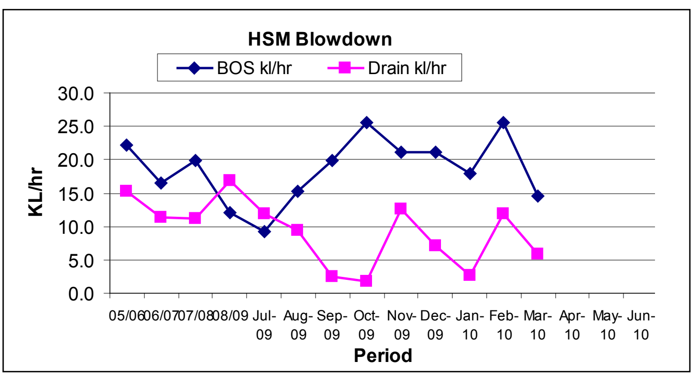


Figure 6.1.2 Blowdown HSM water treatment system BlueScope – Port Kembla Steelworks

6.2 Tenaris Tamsa

Tenaris Tamsa has two hot-rolling mills (LACO and LAM1). Water is used for direct cooling in the hot-rolling processes and for indirect cooling in furnaces and in hot-rolling processes.

Methods applied for pre- and/or post-treatment of the water

Pre-treatment: the main source of water is groundwater, so no pre-treatment is needed.

Post-treatment: direct cooling water system (LACO and LAM1), see diagram below. This system is closed and a water volume <5% of total is discharged.

Approximately 4800m^3 of water is treated a day from the LACO+LAM1 system (direct and indirect cooling water).

Chemicals used

Approximately 350 tonnes/year of the following are used:

- coagulant
- flocculants
- sodium hypochlorite
- biocide
- anticorrosive agent.

Some examples: PCC-404, PCD-2850, PMB-602, Halogene T30, Sosa liquida, sal, Sosa en escamas, Proclean, Sulfito, Depositrol.

Waste production

Sludge: Approx. 1,500 tonnes/year. The amount of waste oil from treatment plants is not known.

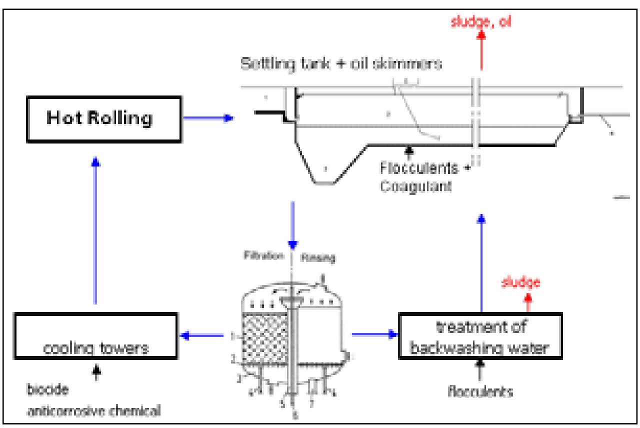


Figure 6.2.1 Simplified flow diagram, water treatment

6.3 CMC Steel Arkansas

Water is used to cool the mill stands (stand rolls) and equipment such as gearboxes (via water/oil heat exchangers). The water is recycled continuously through the mill process. Well water is used as make-up water (to address evaporation).

There is no pre-or post-treatment of water. However, there is an oil skimmer on the mill pond. The pond is a simple in-ground reservoir. The mill pond is dredged every three months and the mill scale (iron oxide) is recycled via a cement plant customer.

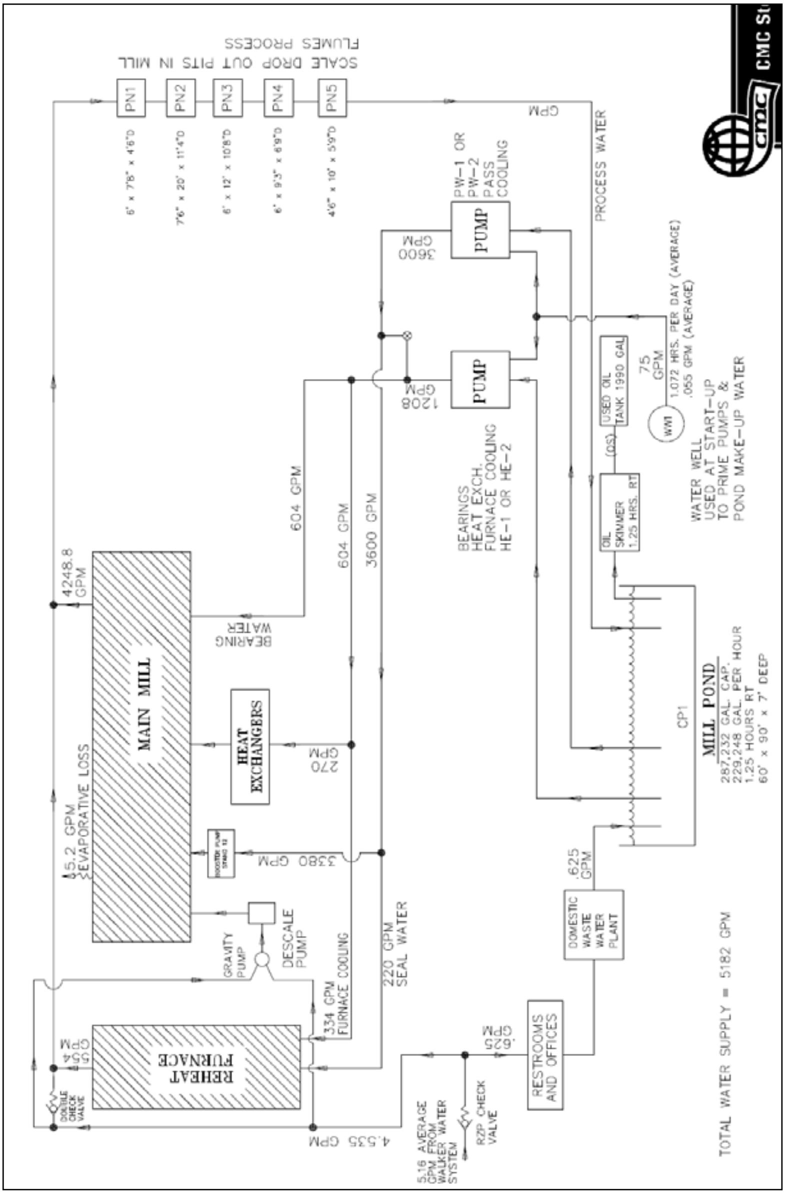


Figure 6.3.1 Schematic drawing of the mill water system

6.4 Tata Steel Europe – Port Talbot

Hot mill recirculating water systems

All the Port Talbot steelworks hot mill recirculating water systems run in one substantial loop and all the water used is returned for cleaning and reuse. Some losses occur within the processes from evaporation and so on, and lost water is topped-up from the works reservoir. The reservoir itself is topped-up by abstracting water from the Eglwys Nunydd Reservoir.

The water passes through various meshes and a rotary filter to remove larger debris that may have been drawn into the system and pumped to the works reservoir. As required, water drawn from the works reservoir passes through additional screens before entering the hot mill water treatment system.

The table below shows a typical analysis of works reservoir water.

Works reservoir water	
Total alkalinity	80 mg/l as $CaCO_3$
Calcium hardness	75 mg/l as $CaCO_3$
Total iron (Fe)	1 ppm
Soluble iron	0.1 ppm
Suspended solids	8 ppm
Chloride	40 ppm
pH	8 ppm
Conductivity	300 µS
Oil	4 ppm

Table 6.4.1 Typical analysis of works reservoir water

Hot mill recirculating water systems

There are a number of different water systems in use within the hot mill recirculating water system, each with a different quality (cleanliness) and pressure. Most of these systems were upgraded in the 1980s. The three main types are called 'service' water, 'descaling' water and 'roll coolant' water (see figure below).

Roll coolant water is of the highest quality, followed by descaling water, and service water is the lowest quality water. Water pressures for the three systems are typically 3.5 bar for service water, 8-10 bar for roll coolant water and 150-180 bar for the descaling water.

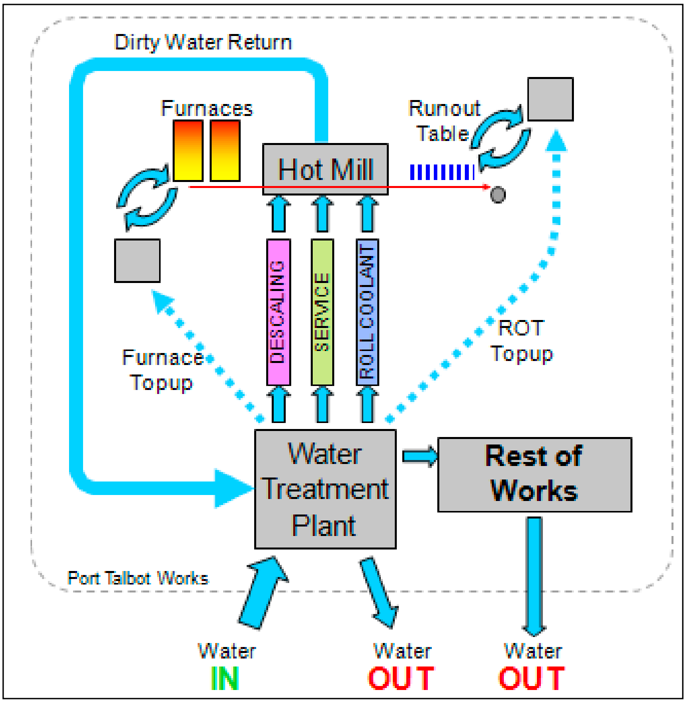


Figure 6.4.1 Simplified overview of the hot mill recirculating water systems

Prior to use, the descaling and roll coolant water is subjected to a single pass through sand filters. The service water is not treated apart from being run through screens. The total hot mill recirculating system water usage includes 4,460m^3/hour for the roll coolant, 2,560m^3/hour for service water and 360m^3/hour for descaling or in proportions 60%, 35% and 5% for roll coolant, service and descaling water respectively.

Hot mill water reuse and top-up

All the wastewater from the hot mill is returned via the 'dirty water return' main for cleaning at the New or Old Canal by sedimentation process and oil skimmers. It is then reused, as shown in the figures.

Thus, apart from evaporation losses, the vast majority of water used in the hot mill is continually recycled to the water treatment plant for reuse. However, this re-circulation system is not closed as the water treatment plant also supplies most of the rest of the Port Talbot works with water.

The total flow rate of the Dirty Water Return is ~7,400m^3/hour and there is a top-up of ~400m^3/hour for the recycling hot mill water systems from the works reservoir to the water treatment plant, which totals an input of ~7,800m^3/hour to the hot mill water systems.

6.5 China Steel Corporation

Hot strip mill wastewater treatment plant – electro-dialysis reversal (EDR)

Due to the potential shortage of freshwater in the Kaohsiung area of southern Taiwan and the fact that the chloride and calcium concentration of the direct cooling water to No. 2 hot strip mill needs to be controlled below 300 ppm, water must be discharged. Circulating water and make-up freshwater have to meet the mill's requirements.

An average of 20,000~30,000tonnes/month of freshwater is produced to maintain calcium concentrations below 300 ppm. To realise the water-saving policy of the company, CSC started an EDR pilot plant test to evaluate the feasibility of recovering freshwater from the recirculating cooling water two years ago. Based on the good results of this pilot test, the demonstration plant was constructed in 2008. The plant is began operating formally in April 2009.

Influent characteristics

Raw water from No. 2. hot strip mill recirculates direct cooling water. The average input quality is:

pH	8.5	Cl^-	280 ppm
Conductivity	1,800μS/cm	$SO_4^=$	340 ppm
Total hardness	400 ppm	Ca^{++}	300 ppm
M-alkalinity	130		

Data	pH	Conductivity μS/cm	Ca-Hardness ppm	Cl^- ppm
2008/12/6	8.62	1,374	250	225
2008/12/7	8.55	1,440	236	240
2008/12/8	8.56	1,417	250	232
2008/12/10	8.43	1,366	296	209
2008/12/11	8.57	1,342	248	206
2008/12/12	8.57	1,325	240	204
2008/12/13	8.45	1,358	240	205
2008/12/17	8.68	1,382	262	208
2008/12/18	8.61	1,351	258	212
2008/12/19	8.48	1,468	268	224
2008/12/20	8.53	1,455	260	212
2008/12/22	8.47	1,464	264	220
2008/12/23	8.58	1,478	250	212
2008/12/24	8.56	1,313	250	212

Table 6.5.1 Quality of EDR raw water (No. 2 hot strip mill direct cooling water system)

Dimensions of the EDR plant

The area of the EDR treatment plant is 20.5m by 9m. Present capacity of this plant is 550m^3/day. The recovery rate can reach 75%, running cost is about 17 NTD/m^3 (~<US$0.6/m^3).

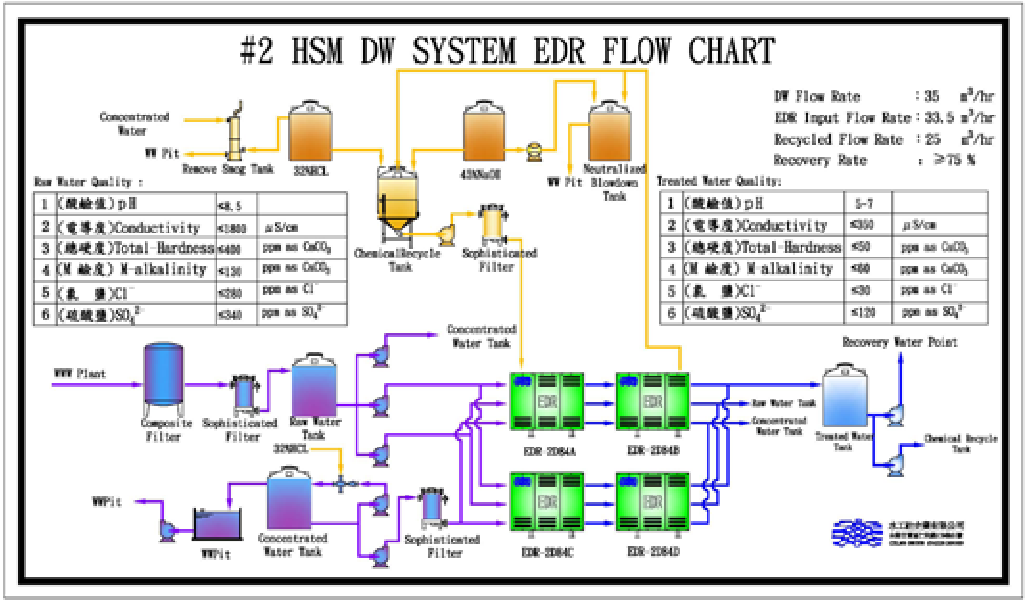


Figure 6.5.1 Flow chart of the EDR plant

Wastewater of the EDR plant

Through a two-step filtration process the direct water system blow-down goes into the raw water tank. Then the raw water is pumped into the EDR modules (along with two recycling streams: one stream is continuously recycled concentrated water, the other stream is continuously cooling electrode plate). Finally, high voltage electricity (< 140 Volt) is applied to anion and cation membranes to separate the raw water into two streams (treated and concentrated water).

The treated water is delivered to a storage tank for use as make-up water for the cooling tower. The concentrated water is delivered to a concentrated water tank and recycled, where pH must be controlled below 6.5 to prevent scaling tendency. If the treated water quality (conductivity) is declining, chemical cleaning should be carried out to resume the system. If concentrated water conductivity is too high, then the water is discharged to the wastewater plant.

Conventional electro-dialysis systems tend to have scaling problems, which result in shorter running times. However, this plant uses the EDR system where "reversal" means to change the directions of concentrated and treated water streams by reversing the voltage direction every hour. This can reduce the scaling tendency and keep the plant running longer without serious scaling.

Effluent characteristics

The quality of the treated wastewater as it was in 2008 is shown in the table below. Tests showed that the rejection rates are 75~82% for conductivity, 96~98% for Ca-H and 92~96% for Cl^-. The pH of treated water (4.7~6.0) is lower than the pH of raw water (8.0~8.4) but the treated water capacity of the EDR plant is only about 550m^3/day. Compared to the direct cooling water system recirculation volume of 11,000~12,000m^3/h this is too small, so the pH value of No. 2 hot strip mill direct water does not change.

Data	pH	Conductivity µS/cm	Ca-Hardness ppm	Cl^- ppm
2008/12/6	5.9	280	4	8
2008/12/7	5.2	317	7	11
2008/12/11	5.8	248	4	7
2008/12/12	5.8	250	4	7
2008/12/17	6.7	235	4	8
2008/12/18	6.5	267	4	8
2008/12/23	6.4	338	4	20
2008/12/26	5.6	287	6	13
2008/12/30	5.1	246	8	16
2008/12/31	4.7	248	2	1.5
2009/1/6	6.1	296	8	10
2009/1/8	5.5	257	7	8
2009/1/12	5.5	268	8	11
2009/1/16	5.7	308	8	11

Table 6.5.2 Quality of treated water (as direct cooling water system make-up)

Conclusions

The return on investment of the EDR plant is very good. Before the EDR plant was put into operation, 20,000 tonnes/month of make-up water was needed. Only 2-3,000 tonnes/month is needed now. Make-up water is reduced by 90%.

In addition to the quantity reduction, this plant can recover treated water with better quality. For example, conductivity can be reduced from 650µs/cm to 350µs/cm. Chloride can be reduced from 50mg/l to 20mg/l.

Case studies: Cold-rolling mill

7.1 Duferco La Louvière

The neutralisation treatment plant is designed to remove iron from the picking line rinsewater and to treat water coming from the HCl recuperation treatment plant. It also corrects the pH value from the wastewater into the discharge range (6÷9).

The plant consists mainly of:

- two neutralisation tanks
- one flocculation tank
- one lamellar separator
- one sludge tank
- one filter press
- one control tank
- one sand filter
- gas scrubber
- control cabinet and instrumentation.

The wastewater is taken from the buffer tanks and pumped to the first of two neutralisation tanks, because two-stage neutralisation gives a steady and easily controllable process. Compressed air for oxidation of the iron is also delivered. If necessary, pre-neutralisation can be performed by two old neutralisation basins before sending the flow to the neutralisation treatment plant (see figure below).

In the first neutralisation tank a coarse pH correction (pH 4-11) is performed by dosing sodium hydroxide (NaOH). After that, the water flows freely from the first into the second tank by means of a minor difference in water level. In this second tank a fine pH correction (pH6.5-8.5) is performed by dosing sodium hydroxide (NaOH).

All the Fe^{2+} present will be oxidised to Fe^{3+} by the oxygen from the air. As sodium hydroxide is added, solid $Fe(OH)_3$ will be formed in an alkaline environment. Both tanks are equipped with agitator, a pH measurement and an air distribution network on the tank floor.

The neutralised water flows from the second tank into the flocculation tank by means of a minor difference in water level. In this flocculation tank a flocculating agent (polymer) is dosed for the purpose of agglomerating the small solid $Fe(OH)_3$ particles to a bigger and better settling flakes. The flocculated water flows from the flocculation tank into a lamellar separator. In this separator the flakes slowly settle in the sludge cones, while the clear overflow water flows into the pump tank after passing a lamellae package.

The valves at the underside of the sludge cones of lamellar separator are opened periodically and sludge is drained to the sludge tank using hydrostatic pressure.

The somewhat thickened sludge in the sludge tank is pumped into a chamber filter press with an electrically driven membrane pump. In this filter press, the solid flakes are retained by the filter cloth and the already composed filter cake, while water flows through and leaves the filter press through the filtrate outlets and the filtrate gutter. Since this water may contain too much iron, it is pumped back into the flocculation tank.

The final treatment of the water is filtration by sand. The water then goes to sewage after a pH and turbidity check in the final control tank. All the water tanks in the first step are in vacuum conditions and send gas to a wet scrubber. A part of wastewater flow coming from scrubber is sent to the first neutralisation tank.

Dimensions and technical data

The capacity of the neutralisation unit is $15m^3/h$.

The pre-neutralisation tanks volume is 2 by $21m^3$, the neutralisation volume is $15m^3$ for each neutralisation tank, flocculation tank volume is $4m^3$ and decantation volume is $10m^3$.

The NaOH (solution 22%) consumption is approximately 6t/d.

	pH	Total Iron [Fe] mg/l	TSS mg/l
Inflow	>1	300	
Outflow	6.5 – 8.5	<6	<40

Table 7.1.1 Inflow and outflow

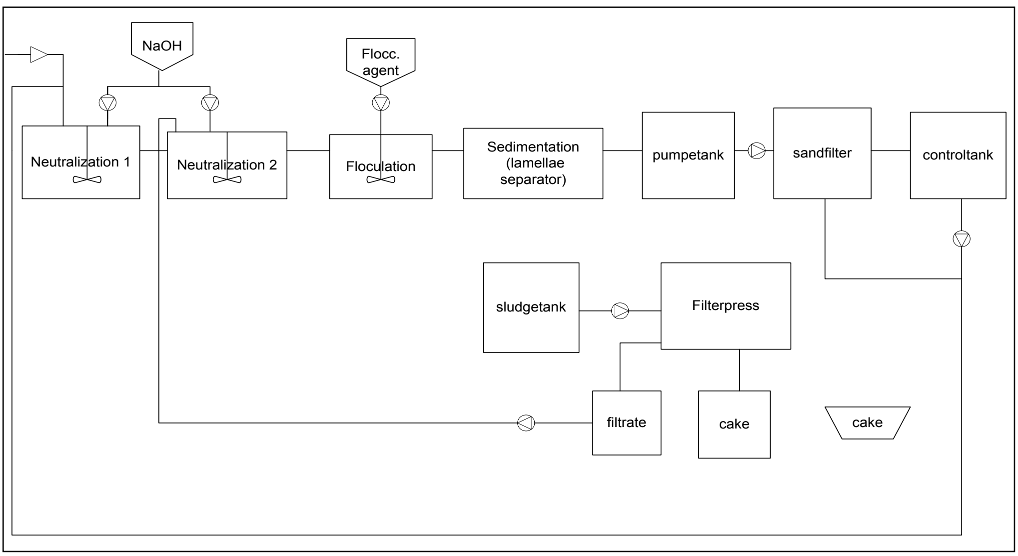


Figure 7.1.1 Simplified flow diagram

Figure 7.1.2 The two neutralisation tanks and the flocculation tank

7.2 Arcelor Mittal Ghent

Wastewater treatment in the cold-rolling mill

Before the hot-rolled coils can be cold rolled, the thin scale layer that was formed after hot rolling must be removed. To this end, the steel strip is treated with a hot hydrochloric acid solution, a process referred to as pickling.

The pickled coils are next reduced in thickness in a tandem mill by a combination of high traction and compression. In both processes water is used for process and cooling purposes. Depending on the application, a different water quality is used. As a rule of thumb, water in direct contact with the end product is nearly completely desalinated. Feed water for closed cooling circuits is partially desalinated and feed water for semi-open cooling circuits is brackish surface water.

Waste process water, after treatment in wastewater treatment facilities, and cooling water (after cooling with an atmospheric cooling tower) are recycled to the main water intake point for further use. Besides some evaporation there is no water loss in the pickling and cold-rolling mills.

Wastewater treatment pickling lines

Wastewater produced in the pickling lines and the pickling acid regeneration ovens have a pH of around 1.5 and an iron concentration of up to 5g/l. The wastewater flow to treat is about $50m^3/h$.

Strong acid wastewater, containing 10-15% Fe and up to 20% hydrochloric acid, originating from emergencies (e.g. due to a failing sealing) is stored separately. From this storage tank the wastewater is gradually added to the wastewater treatment plant influent in order not to disturb the wastewater treatment efficiency.

In a physical-chemical treatment plant the acid is neutralised with lime, iron present as Fe_2+ is oxidised to Fe_3+ by air injection and next precipitated as $Fe(OH)_3$. The $Fe(OH)_3$ flocs are removed in a settling tank, the decanted sludge is dewatered with a vacuum drum filter. The filter cake is externally recycled.

The treatment plant consists of a 500m^3 buffer tank which feeds a 20m^3 mixing tank. In this tank lime addition and a partial oxidation takes place. Then the water flows into a 30m^3 oxidation tank, where an additional pH check and adjustment and aeration takes place. $Fe(OH)_3$ flocs are subsequently removed in a settling tank, decanting is improved by adding a polymer as flocculant. The separated sludge is pumped to the vacuum drum filter.

The plant operates in an automated mode. The effluent quality is controlled for turbidity and pH. The pH of the clarified water varies between 7 and 8, the Fe concentration is <3 ppm and the suspended solid concentration is typically between 20 to 30 ppm.

Figure 7.2.1 Overview of the physical-chemical treatment plant of the pickling lines

Treatment of oily wastewater

The use of oil/water emulsions in cold rolling is necessary for cooling and lubrification purposes. During the rolling process these emulsions pick up iron particles and the rolling oil deteriorates, thus influencing the rolling mill performance in terms of productivity and product quality. As a consequence, the emulsion has to be renewed and there is a continuous purge of used emulsion thus creating an oily waste stream, with an average oil concentration between 0.5% and 1%.

ArcelorMittal Ghent chose to treat the waste emulsion by ultrafiltration because of the following considerations:

- the efficiency of this technique is less influenced by the chemical nature of the influent then physical-chemical techniques
- the addition of chemicals is not required
- no generation of oily sludge
- nearly 100% oil removal efficiency independent of the influent oil content
- automation possibility
- operator errors are excluded.

Membrane fouling results in a high cleaning frequency and thus a lower average permeate flux, due to the presence of high concentrations of suspended solids and the presence of free oil. To deal with this problem, the waste emulsions are stored in 250m^3 large settling tanks. In this pre-treatment station the waste emulsions are kept on a temperature of about 40°C to improve the free oil separation, which is skimmed off and pumped to the waste oil treatment plant.

The pretreated waste emulsion (no free oil and a reduced suspended solid concentration) is then pumped to a recirculating tank (2 x 55m^3). From these tanks (one tank for two ultrafiltration units) the emulsion is pumped through the ultrafiltration skids in a closed loop. By each passage through the membranes emulsified oil droplets and suspended solids are retained and concentrated. Water and some low molecular weight materials pass through the membranes. The concentrated flow goes back to the recirculating tank thus increasing the oil concentration (which is continuously monitored) in the recirculating tank.

Ultrafiltration is a cross-flow filtration process, which means that unlike ordinary filtration there is no build-up of a cake of retained material. The permeate flux is influenced by the temperature of the waste stream to be treated, the transmembrane pressure, the oil concentration, the tangential velocity, the membrane nature and the fouling factor.

The membrane with the lowest fouling potential on waste emulsions was selected based on the results of long-term pilot tests. A tubular organic membrane manufactured by the company KOCH seemed to be the most appropriate membrane. Chemical and mechanical cleaning of the membrane is also facilitated by this membrane configuration.

When the permeate flow decreases below the minimum flow the ultrafiltration is automatically cleaned by recirculating an appropriate chemical through the membranes with the chemical cleaning equipment. The efficiency of the cleaning is monitored and when the original permeate flux is reached the ultrafiltration unit goes back in production mode. The contaminated cleaning solution is drained off to the pre-treatment station.

The permeate is oil-free but has a chemical oxygen demand of about 2,500 ppm O_2/l due to the passage of low molecular weight components through the membranes.

There are four ultrafiltration units with each a capacity of 2.5m^3/h. Each unit has 204 membranes (1-inch diameter, 3m length) arranged in 34 rows of six membranes resulting in a total membrane surface of about 40 m^2 per skid (see figure below). The waste emulsion is pumped through the membranes with a driving pressure of 4 bar, a velocity of 5m/s and a temperature of 40°C.

The whole plant is fully automated, there is no local operator and inspection is limited to a daily routine check.

The permeate flows via the industrial sewage canal from the finishing mill to a pumping station from where it is recycled to the main water intake of the plant and thus available for reuse. The impact of the chemical oxygen demand (COD) of the permeate on the COD of the distributed water is negligible, thus requiring no further treatment.

Figure 7.2.2 The four ultrafiltration skids

7.3 China Steel Corporation

There are three main wastewater types at the cold-rolling mill: waste acid, alkaline and grease wastewater. This are from different cold-rolling mill lines, including:

- acid regeneration plant (ARP)
- pickling and cold-rolling mill (PLCM)
- electrolytic galvanizing line (EGL)
- hot-dip galvanizing line (CGL)
- continuous annealing line (CAL) and
- electrical steel coating line (ESCL).

In the cold-rolling mill's wastewater treatment plant a combined series of treatments including DAF (dissolved air flotation), API oil separator, coagulation, flocculation and filtration processes take place. This wastewater treatment plant has been in operation since 1991.

Influent characteristics

The acid wastewater is from the mill pickling and the roll products surface cleaning with hydrochloric acid, so the wastewater has relatively low pH and a high concentration of ferric and ferrous compounds.

The alkaline wastewater comes from cleaning products with detergents, so the wastewater has relatively high pH and COD.

The third part of wastewater is the grease wastewater which comes from the pickling and cold-rolling mill and contains lots of oily sludge and high concentrations of COD.

The influent characteristics of the cold-rolling mill wastewater treatment plant are shown as in the table below.

Wastewater		pH	COD mg/l	S-Fe mg/l
Acid wastewater	ARP/TCM	1.9		3,545
	PLCM	1.9		413
	EGL with Zinc	1.1		3,354
Alkaline wastewater	CAL	12.2	956	
	EGL	10.8	154	
	CGL	9.4	325	
	ESCL	9.7	317	
	CAL temper mill (few)	8.1	28,100	
Grease wastewater	TCM/PLCM	4.6	2,054	

Table 7.3.1 Influent characteristics (average)

Description of the wastewater treatment plant

The three different kinds of wastewater are treated individually. After pH adjustment, suspension solid removal and the removal of floating or settled oily sludge, all the streams combine and go through the coagulation and flocculation processes.

The pre-treatment for treating acid wastewater is pH adjustment to 9 by sodium hydroxide addition. The alkaline wastewater is pumped to the dissolved air flotation (DAF) process.

The oily sludge of the grease wastewater is removed in an API process and pumped into a DAF process. There is a zinc reduction process by coagulation and flocculation for the high zinc acid wastewater of the electrolytic galvanizing line. From the clarifier the slurry goes to the zinc sludge settling. From there it is dewatered as zinc sludge cake, so zinc recovery is implemented.

After these pre-treatments the wastewater and overflow of treated water with the zinc from the clarifier come together in a main process which starts in the first equalisation basin. The wastewater pH is adjusted to about 10 by sodium hydroxide and calcium hydroxide addition in a neutralisation basin.

Following the second coagulation, flocculation takes place in a basin where ferric sulfide and polymer is added. Then the stream flows to the clarifier basin for flock settling. After the thickener, the settled sludge is dewatered to sludge cake by other filter presses. Finally, the sludge cake is carried to incinerator.

After a filtration process the wastewater is pumped to the final industrial wastewater treatment plant to lower residual SS. The wastewater treatment procedure is shown below.

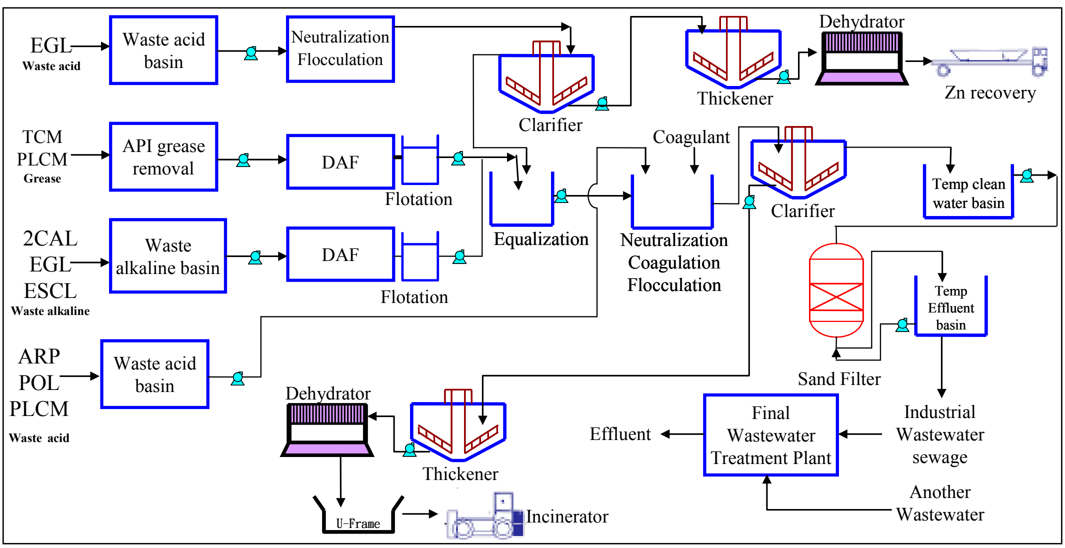


Figure 7.3.1 Cold-rolling mill wastewater treatment plant at China Steel Corporation

Dimensions of the plant

The hydraulic retention time (HRT) of the first coagulation and flocculation basin for the zinc acid wastewater is about two hours with 5% x 26 CMH calcium hydroxide and 720l/h polymer added. The volume of the equalization basin is 2,000m^3 with 240 CMH designed inflow capacity.

The HRT of the second coagulation and flocculation basin for the combined wastewater is approximate 1.7 hours with the designed 50l/m x 45% sodium hydroxide, 10l/h x 10% ferric sulfide, 1CMH 5% calcium hydroxide and 1,615l/h polymer added. The diameter of clarify is 20m and the surface loading is about 18m^3/m^2/day.

Effluent characteristics

The effluent of the cold-rolling mill wastewater in 2008 is shown in the table below. The removal efficiency of soluble ferric and ferrous composition is excellent. Nevertheless, the residual COD concentration of the discharged wastewater is still high. To meet the mandatory regulation standard, this wastewater is pumped to an industrial wastewater treatment plant.

Parameter	Unit	Average
pH	-	10.3
COD	Mg/l	133
SS	Mg/l	39
Fe (soluble)	Mg/l	0.53

Table 7.3.2 Discharged wastewater quality (2008)

Case study: Finishing/Galvanizing

8.1 voestalpine Stahl

voestalpine operates five hot-dip galvanizing lines at Linz. Most of the steel galvanized at the plant is cold-rolled. It is also possible to produce a variety of grades with intermediate process steps such as galvannealing, phosphatising and passivation.

The following is a description of the process and wastewater treatment system in hot dip galvanizing line 3.

The hot-dip galvanizing line essentially consists of the following systems:

- entry section, including pre-material stock and coil entry transport
- strip cleaning, including a lye recovery system
- heat-treatment unit with a pre-heating furnace, annealing furnace and HNx cooling systems
- metallic bath
- cooling tower
- skin-pass mill stand and tension leveler
- chemical passivation
- exit section, including finished material stock and coil exit transport.

Types of wastewater

The following types of wastewater occur during the hot dip galvanizing process:

- cooling water, once-through cooling, with drainage into the Danube river
- concentrates from full desalination, with drainage into the Danube river
- process water, with drainage into the municipal wastewater treatment plant for final biological cleaning.

Cooling water, once-through cooling

There are two separate and closed-system circuits equipped with heat exchangers to cool the furnace, the air-conditioning system and so on. River water is used for re-cooling in the secondary system, after which it is returned to the Danube.

The once-through cooling system at voestalpine in Linz was chosen for its location on the outskirts of the city. The use of once-through cooling instead of cooling towers ensures that no water vapour can escape during the winter and cause industrial snow and icy streets. The once-through cooling system is only possible because the Danube has a sufficient amount of water flow volume. The temperature of the water as it is drained into the river is documented by an immission-based temperature monitoring software program.

Desalination concentrates

The skin-pass mill and cleaning systems are supplied with fully desalinated water that is produced in a reverse osmosis system. The concentrates from regular operation are drained into the Danube after inspection.

Process water

Production operations such as skin passing, strip cleaning and passivation yield a certain amount of wastewater.

Skin-pass mill

The wastewater from the skin-pass mill is collected and pre-cleaned to remove grease and oil by means of sedimentation, oil separators and gravel filters. The wastewater is cleaned in a final cleaning process in an external large-scale biological treatment plant.

Strip cleaning

The wastewater from strip cleaning is piped to a treatment plant where it is pre-cleaned in a chemical/physical process. The essential pre-cleaning process steps are the separation of solids, neutralisation and filtration. After being properly inspected, the treated wastewater is piped to an external large-scale biological final treatment plant.

Passivation

The inorganically burdened wastewater from passivation is pre-cleaned together with the process water as described above and finally cleaned in a large-scale treatment plant.

Organically burdened wastewater is collected and treated externally.

To ensure environmental compatibility a software program measures and documents the values of the water drained into the river as it leaves the large-scale treatment plant.

Case studies: Alternative steelmaking techniques

9.1 Tenaris Siderca - Midrex DRI

Direct reduced iron (DRI) plant, Midrex process

This plant uses the Midrex direct reduction technology, in which reformed natural gas reduces iron oxide to sponge iron. The plant consists of a 4.98m diameter vertical shaft reduction furnace, a compressor and heat recovery system area and a reformer furnace which converts natural gas to hot reducing gas.

The purpose water is used for:

- process water for cooling and cleaning process gas, gas cooling and gas seal in open system - about 1,600m^3/h from river water
- cooling water for process and cooling gas compressors in open loop, about 8m^3/h from cooling tower
- cooling water for machinery and seal gas compressors is a close loop systems (Chromate treated water to prevent corrosion) and the make-up is almost zero.

Pre- and/or post-treatment of water

Pre-treatment: the main source of water is from the river. After passing through 500 micron filter, the water is stored in a pool and then distributed to direct reduction.

Post-treatment: sedimentation and sludge dewatering.

Sedimentation is carried out in two pools used one at a time. The sludge by -product is removed mechanically. After the sedimentation pool the water quality is:

Parameter	Unit	Average
pH		7.6
Temperature	°C	39
Fe-total	mg/l	19.7
Fe-soluble	mg/l	0.02
SSEE	mg/l	5.6
THC	mg/l	0.3
Solids	mg/l	<0.1

Table 9.1.1 Water quality 2008, average data

No chemicals are used for the process water system. The cooling tower uses an anti-fouling agent and an anticorrosive agent. The closed loop cooling water uses chromate.

Approximately 15,000tonnes/year of sludge is produced. Siderca considers this a by-product.

9.2 Essar Steel Hazira, India – Briquetting

Hot briquetted iron (HBI) plant, direct reduced iron (DRI), Midrex process

The direct reduction process converts iron oxide to a highly reduced product suitable for steelmaking. To achieve this conversion, reducing gases are used to extract chemically-bonded oxygen from iron oxide.

The reduction takes place at elevated temperature but below fusion temperature of the feed material using hydrogen and carbon monoxide as reducing gases. These gases are produced in the reformer and introduced into the furnace at controlled parameters. Hydrogen and carbon monoxide extract oxygen from iron oxide, yielding a highly reduced product.

The two principle components of plant are the shaft furnace and the gas reformer.

The iron oxide material of pre-determined feed mix, mainly lump ore and pellets, descends from shaft furnace charge hopper by gravity into the furnace. The feed rate is controlled by discharge rate at the bottom of the furnace. The reformed gas at controlled temperature and composition is introduced into the furnace and reducing gases flow counter-current to the feed. The gases heat the material to the reduction temperature whereby hydrogen and carbon monoxide react with iron oxide to form water and carbondioxide and leave metallic iron and gangue in the product.

Reactions: Furnace

(A)	$3Fe_2O_3 + CO$	endo ----------->	$2Fe_3O_4 + CO_2$	Above 200°C
	$3Fe_2O_3 + H_2$	exo ----------->	$2Fe_3O_4 + H_2O$	Above 200°C
(B)	$Fe_3O_4 + CO$	endo ----------->	$3FeO + CO_2$	Above 570°C
	$Fe_3O_4 + H_2$	endo ----------->	$3FeO + H_2O$	Above 570°C
(C)	$FeO + CO$	exo ----------->	$3Fe + CO_2$	Above 750°C
	$FeO + H_2$	endo ----------->	$3Fe + H_2O$	Above 750°C

The reducing gas is generated in the reformer by catalytically reforming a mixture of fresh natural gas and recycled top gas from the shaft furnace. The reformer is a refractory-lined furnace containing alloy tubes filled with a nickel-based catalyst.

The feed gas mixture flows upward through the catalyst bed where it is heated and reformed. The reducing gas leaves the reformer at near equilibrium conditions, containing 90% to 92% hydrogen and carbon monoxide. The gas is then directly conveyed to the shaft furnace.

Reactions: Reformer

(A)	$CH_4 + CO_2$	endo ---------->	$2CO + 2H_2$	Above 880°C
(B)	$CH_4 + H_2O$	endo ---------->	$CO + 3H_2$	Above 850°C

The thermal efficiency of the reformer is greatly enhanced by the heat recovery unit, called the recuperator. This unit consists of two shell and tube type heat exchangers in the flue gas duct coming from the reformer. The heat exchangers recover the sensible heat from the reformer flue gas to preheat combustion air (used in the reformer burners) to 675˚C and to preheat the process gas (mixture of top gas and natural gas fed to the reformer tubes) to 540˚C.

After reduction in the furnace, hot reduced iron at 650˚C is fed into briquetting presses for compression to produce HBI. The formed hot briquettes are cooled by quenching in water bath. The cooled briquettes are transported via conveyor system to the briquette yard, bunker or sent to the steel melt shop. Fines separated in quench tanks from HBI are removed and stored separately as product fines.

The plant also has an in-house developed facility of hot discharge. The reduced iron in lumps and pellets is directly fed to the hot DRI vessels of 90 MT capacity, by-passing the briquetting machines. The vessel is mounted on a trailer which is then transferred to steelmaking shop, where it is directly fed into the electric arc furnace. This saves a lot of energy which otherwise is wasted quenching the briquettes.

HBI water system

Essar Steel has five modules (plants) for natural gas based iron ore reduction. Here details of Module 1 to 4 are described. Module 5 is located at the same premises but at a different location, however its process water treatment is identical.

Use of water

- non-process use: drinking, sanitary and horticulture
- process/plant use: cooling water, conventional open and closed cooling water systems
- process water: process gas cooling, cleaning, dedusting
- process/system: dynamic sealing (water seals).

Water treatment methods

A. Pre-treatment/Raw water treatment: raw water clarification, pressure sand filters, disinfection for drinking water, water softening for cooling water.

B. During process/In-plant/Cooling water treatment: clarification, sludge dewatering, cooling water treatment.

C. Post-treatment/Effluent treatment: oil removal, pH correction.

A. Pre-treatment/Raw water treatment

Capacity: 7,000m^3/day

At a flow rate of 300m^3/h raw water is pumped to a flash mixer where it is mixed for 15 minutes with aluminium and enters a clarifier. For three hours in the clarifier suspended solids are settled and clarified water with less than 10 nephelometric turbidity units (NTU) overflows to a sump. Clarified water is filtered in pressure sand filters. When filter media gets clogged, backwash will take place with clarified water and backwash water is diverted to the flash mixer for reuse.

After disinfection (chlorination by sodiumhypochlorite solution) 1,000m^3/day of filtered water is supplied as drinking water to the plant and to surrounding villages.

For make-up at the cooling towers filtered water is diverted to softeners where temporary hardness/calcium, magnesium are replaced with sodium ions. Approximately 4,500m^3/day of soft water is used as make-up for the open and closed cooling water systems of the HBI plants. Ion exchange resins are regenerated by injecting common salt/brine solutions. Except if with high salt/sodium chloride, entire regeneration/wash water is diverted to horticulture water sump for watering the gardens.

About 1,500m^3/day treated water is supplied to a captive power plant located at the HBI complex.

B. During process/In-plant/Cooling water treatment

1. Closed machine cooling water system

Combined circulation rate for 4 plants 300m^3/h with system hold up volume of 40m^3. Small systems for cooling of precious/delicate systems of the HBI Briquetting Machines are chemically treated with sodium nitrite/borax and 2kg/week dosing of non oxidising/anti-foaming biocide. Water losses only through pump packings and machinery rotary connections. Soft water is used as make-up for cooling water.

2. Machinery open cooling water system

The combined circulation rate for four plants is 500m^3/h. A conventional cooling water system is used for heat exchangers, furnace hydraulics/shafts cooling, compressor jackets, water-cooled motors, valves on high temperature gas lines, as spray water for rotary compressor lobes, sealing for water ring compressors. Zinc/phosphate polymers, dispersant treatment and once a week non-oxidising anti foaming biocide dosing.

Water losses: cooling tower evaporation/drift losses, minor leaks from pump glands.

There is involuntary blow down of 2,000m^3/day because water used as spray water and sealing water for compressors gets contaminated with iron, calcium, magnesium and cannot be recycled to the open machine cooling system, so it is used as make-up water for already contaminated water systems. Generally, soft water is used as make-up water.

3. Semi-contaminated cooling water system

The combined circulation rate for four plants is 1,600m^3/h for direct cooling/cleaning of small gas systems with gas flows less than 10,000m^3/h and very low suspended particulates. The main contaminants in return water are carbon dioxide, calcium/magnesium compounds and silica.

The only chemical treatment done is non-oxidising antifoaming biocide charging, once a week.

Water losses: cooling tower evaporation/drift losses, small losses through pumps packing. Cooling water system purging, if required, is used as make-up water for contaminated water systems. Also EPOL blow down recycled water or untreated raw water is used for make-up.

4. Contaminated water system

This is the most complex and largest water system with 8.000m^3/h combined circulation for four plants. The total system hold up volume is more than 20,000m^3. Every hour, more than eight tonnes (200 tonnes/day) of solids, mainly iron/iron oxide fines, are removed from the system water before it is recirculated.

The water is used for cooling, cleaning and dedusting of the total process gas circulated from the HBI direct reduction furnace to reformer. Every hour, in each HBI plant,150,000 m^3 of gas (CO_2, CO, H_2O, H_2, with fines of iron/iron oxide, lime, other earth metal compounds) leaves the furnace at 400°C and enters the top gas scrubber, where 1,500 to 2,000m^3/h contaminated process water is sprayed for cooling, cleaning and dedusting.

Clean, cooled process gas is diverted to reformers by process gas rotary lobe compressors. In the reformer, CO_2/H_2O reacts with CH_4 in the presence of catalysts to form CO/H_2 or reformed reduction/bustle gas which enters the direct reduction furnace for reduction of iron ore/oxide.

Water with dissolved and suspended contaminants flows to a clarifier where suspended solids are removed by dosing anionic flocculants. Clarifier underflow (slurry) is settled in tailing ponds and clean water is recycled. After cooling in cooling towers, clarifier overflow water is recirculated to scrubbers.

Contaminated water is also used for direct cooling of product from the HBI, dust collection systems, bubblers (dynamic water seals to maintain process system pressure).

Anionic polymer flocculant is the only chemical used this system.

Water losses: cooling tower evaporation and drift losses, evaporation in the process (temperatures up to 70°C). Hot return water flows and cascades at many places.

Cooling water blow down to maintain chloride concentrations below 500 ppm. EPOL blow down recycle water or untreated raw water is used for make-up.

C. Post-treatment/Effluent treatment during process

The only effluent from the HBI plant is blow down water from the contaminated water system. It has nothing which requires any post-treatment or effluent treatment. Suspended solids are already removed at the clarifier before the water enters the cooling towers.

As HBI is using EPOL blow down water with 300 ppm chloride as make-up water, blow down from HBI is done to maintain chloride below 500 ppm. All contaminant levels in HBI effluent are far below the Indian or international norms for post-treatment. Only an oil skimmer is installed to maintain oil concentrations in the effluent below 1 ppm.

Figure 9.2.1 Raw water treatment plant and reservoir

Amounts treated, removal efficiencies, capacities, design criteria

Raw water treatment: 7,000m^3/day, running at 100% of its capacity with same efficiency.

EPOL blow down recycle water: 6,000m^3/day. This is the design capacity but the availability depends on the purging rate by Essar Power Ltd. Also, Essar draws raw water from the river and in India, being a tropical country, river water quality and quantity deteriorates after the monsoon.

So recycled water consumption varies between 3,000 to 5,000m^3/day depending on their cooling water and river water quality.

Type of water	pH	Total hardness	Ca Hardness	Turbidity	Conductivity	Alkalinity	TSS	Chloride
Raw water	8.25	210	100	70	650	225	20	80
Soft water	7.6	3	1	<1	750	225	0	8
Effluent	8.2	125	70	20	1,400	250	10	400

COD/BOD of the effluent is always less than 30/10 ppm.

Table 9.2.1 Quality of treated water

Treatment chemicals and waste production

Raw water treatment plant

Chemicals used: common salt, non ferric aluminium, sodiumhypochlorite

Waste generated: 200kg/day, sludge from clarifier underflow

Process/Plant water system

Chemicals used: anionic poly acrylamide, sodium nitrite/borax, zinc/phosphate polymer, dispersant, non-oxidising anti-foaming biocide

Waste generated: no solid waste is generated. All sludge/plant clarifier underflow is settled in tailing ponds and solid sludge from these ponds is raw material for sinter plant and pellet plant.

Effluent generated: 3500m^3/day (cooling water blow down)

Additional information

During the last two years, two innovative projects were implemented:

1. Converted process adversity into advantage, natural disinfection of process contaminated water systems (see above for details about the process in the contaminated water system).

For microbial control, every week 400kg biocide was being added to the process contaminated water system of the four plants. With higher plant load water temperature from top gas scrubbers at the clarifier inlet increased from 60°C to 65°C.

Lab experiments showed that at this temperature no microbes (TBC and SRB) were present in the process contaminated water. Further experiments at various temperatures and conditions found that at temperatures above 62°C, no bacteria TBC or SRB are present.

This heating method can also be used for disinfection water in the clarifier. If it remains in there for 90 minutes at this temperature level all bacteria will be killed.

Gradually biocide dosing was stopped. Clarifier inlet temperature is maintained above 65°C. For the last two years years no biocide has been applied and no microbes have been detected.

The total saving of non-oxidising anti-foaming biocides is above 18,000kg each year.

2. Effluent to affluent: a 4,500m^3/day effluent water recycle project

Essar Power Ltd is a 620 MW power plant located near the HBI plants. Its effluent water, mainly cooling water blow down is recycled to HBI and used as described above. Its capacity was recently increased from 3,000 to 6,000m^3/day, however actual availability depends on Essar Power's plant load and river water quality. It would be 4,000m^3/day on average.

Case studies: Water and waste management

10.1 POSCO (Pohang Steel Works) - Water treatment system

Ninety-eight percent of the water used in steelmaking processes is reused after the primary treatment in the wastewater treatment facility installed in each unit. The remaining 2% is supplied by an adjacent dam, which reaches a daily average of 174,000m^3.

Pohang Works uses 5.8 million m^3 of circulating water from the steelmaking process every day. If not reused, some of the wastewater processed in the drainage treatment facility is recycled as sprinkler water for dust reduction in raw material yards, and the rest, amounting to 83,000m^3/day, is discharged into the ocean.

POSCO has various water treatment facilities for supply water: wastewater from primary process, final wastewater, rainwater and sewer water. At Pohang there are two wastewater treatment systems: the primary wastewater treatment (WWT) and final WWT. Wastewater generated from coke, BF, FINEX, and STS units goes through the preliminary treatment by each unit. The last treatment is carried out in the final WWT, which is composed of Iron & Steel Making Area Treatment Facility and Rolling Area Treatment Facility.

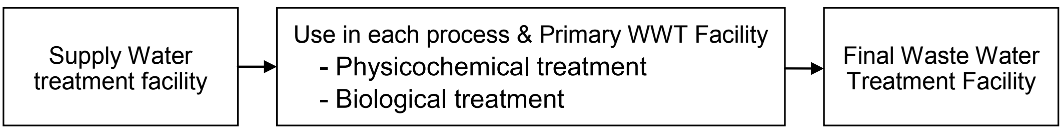


Figure 10.1.1 Overall water treatment process

Treatment of supply water

The water supply facility, which processes some of the supplied water from the dam and provides it to each unit, is capable of treating an average of 250,000m^3 of water a day. This facility is composed of a grit chamber, settling pond, sand filter and others parts, to remove suspended solids (SS). SS are coagulated by an agglutinant in a grit chamber and removed in a settling pond. Through this process, supply water for each plant is produced.

In this supply water facility, 50,000m^3/day of freshwater for industrial purposes is produced, with a turbidity of 1 NTU or below. 180,000m^3/day of clear water is produced. Its turbidity is between 0.1 NTU and 0.2 NTU.

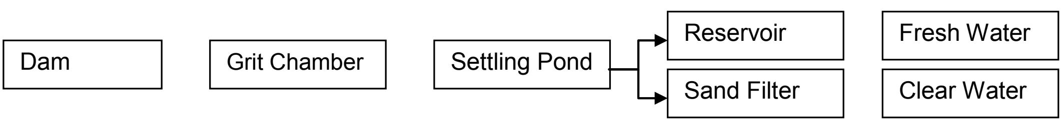


Figure 10.1.2 Supply water treatment process

Physicochemical and biological treatment

Aiming to reduce Total-Nitrogen (T-N), POSCO has brought in a facility for denitrification of discharged water using a microorganism in the coke oven and stainless steel plants. Additional hydrochloric acid facilities (HAF) have been constructed for a drastic decrease in T-N in stainless steel plants.

To reinforce the existing wastewater treatment facilities in coke oven plants, an activated carbon adsorption facility with an average daily capacity of 7,000m^3 was built in 2002. In 2006, POSCO built a biological treatment facility with an average daily capacity of 12,000m^3 in its ironmaking plants.

Items	Unit	Average	Regulations
BOD	mg/l	18	-
COD	mg/l	34	40
SS	mg/l	39	30
T-N	mg/l	38	60
F	mg/l	8	15
CN	mg/l	0.02	1
Zn	mg/l	1.9	5

Table 10.1.1: The Quality of advanced wastewater effluent

Final wastewater treatment

The final wastewater treatment facility can process 50,000m^3/day on average. The facility is composed of an iron and steelmaking area treatment and rolling area treatment to remove SS, COD and others.

The iron and steelmaking area treatment facility was rebuilt in 2006 to improve rainwater separation pipes. The rainwater treatment facility can process 200,000m^3/day on average. The facility consists of nine storage ponds with a capacity of 70,000m^3, four collecting basins with a capacity of 70,000m^3 and a settling basin with a capacity of 200,000m^3.

Water from raw material yards, roads and construction sites is collected into this facility to be processed and recycled, and 44,000m^3 of rainwater is discharged into rivers on a daily average.

Properties of effluent

The wastewater generated from steelmaking processes goes through primary wastewater treatment plants installed at each unit and 98% or more of the treated water is reused. Water that is not recycled during steelmaking undergoes secondary treatment at the final wastewater treatment facilities. It is reused for cleaning roads inside the mill and sprinkling at material yards, to reduce dust. Lastly, the remaining water is discharged to the nearby ocean.

The quality of the discharged water after treatment at the iron and steelmaking area is as follows:

Items	Unit	Average	Regulations
COD	mg/l	25	90
SS	mg/l	6	80
T-N	mg/l	31	60
F	mg/l	6	15
CN	mg/l	0.1	1
Zn	mg/l	0	5

Table 10.1.2 The quality of wastewater effluent of the iron and steelmaking area

10.2 China Steel Corporation - Industrial wastewater treatment plant

The high temperature steelmaking processes means that a lot of water is required for cooling, descaling, dust scrubbers and other processes. The production line will be seriously affected if there is a lack of water. The development of water resources is particularly difficult in southern Taiwan, where traditional water-saving technologies can no longer satisfy the demand. Therefore, China Steel Corporation (CSC) has a policy of to improve the effective use of water resources.

Wastewater reduction, reuse and reclaiming is the best solution. CSC undertook four years of study which included the selection of wastewater stream sources from different processes and conducting a test with a $2m^3$/day pilot model (in cooperation with the CSC affiliated company ECOTEK). After an evaluation, CSC set up a demonstration mini-plant with a capacity of $300m^3$/day. Finally, CSC decided to build an industrial wastewater purification plant (IWWPP) in October 2007.

With the membrane and ion exchanger technologies, IWWPP successfully produced reverse osmosis water and demineralised water for power plant boilers. The total design capacity is $13{,}500m^3$/day which includes $4{,}500m^3$/day of reverse osmosis water and $9{,}000m^3$/day of demineralised water.

Influent characteristics

Eight streams of wastewater from different manufacturing processes were assessed by the central water treatment plant and R&D department of CSC. The assessing parameters included degree of pollution, temperature, flow rate and discharge point.

Wastewater from cooling and the gas scrubbers process were chosen as the influent of IWWPP because of the low conductivity, COD and NH_3-N content.

The influent characteristics are as follows:

pH	6~9
Ca-Hardness	<650 ppm as $CaCO_3$
Mg-Hardness	<200 ppm as $CaCO_3$
M-Alkalinity	<400 ppm as $CaCO_3$
Cl^-	<1.100 ppm as Cl^-
$SO_4^=$	<600 ppm as $SO_4^=$
SiO_2	<20 ppm as SiO_2
Conductivity	<4.500 uS/cm
Temperature	<40°C

Table 10.2.1 Influent characteristics of IWWP China Steel Corporation

The influent for the IWWPP is taken from the sand-filtered water of the industrial wastewater plant. The first step of wastewater treatment is an ultra-filtration (UF) system to remove the suspended solids.

The normal production rate of the UF system is 975m^3/h. The characteristics of UF production water are:

turbidity <0.1 NTU
SDI <3
TSS <3 mg/l.

The second step of the treatment is a RO system to desalinate the ions in the water. The characteristic of RO production water is: conductivity within 100~250µS/cm.

The normal production rate of the RO System is 562m^3/h, and the daily production rate is 14,100m^3/day. About 4,500m^3/day of the RO production water is sent as feed water to inlets of the demineralised water plant of existing power plant No. 2.

The rest of the RO production water about 9,450m^3/day is further treated by the ion exchange process. The characteristics of demineralised water of ion exchange process are:

conductivity <0,2µS/cm
SiO_2 <0,02ppm
Na <0,02ppm.

The normal daily production rate of the ion exchange process is 9,000m^3/day. The treatment system is set with 4,500m^3/day parallel treatment lines. The demineralised water is supplied to demineralised water tanks of power plant Nos. 1 and 2 as the recharging water for boilers.

The recovery rates of the UF, RO and ion exchange processes are approximately 90%, 60% and 95% respectively.

Chemicals used for the abovementioned system are as follows:

UF inlet:	H_2SO_4 and NaOCl
UF cleaning:	Citric acid and NaOCl
RO inlet:	Antiscalants, biocide and $NaHSO_4$
RO cleaning:	HCl and NaOH
Ion exchange resins regeneration:	HCl and NaOH
Neutralisation tank:	H_2SO_4 and NaOH

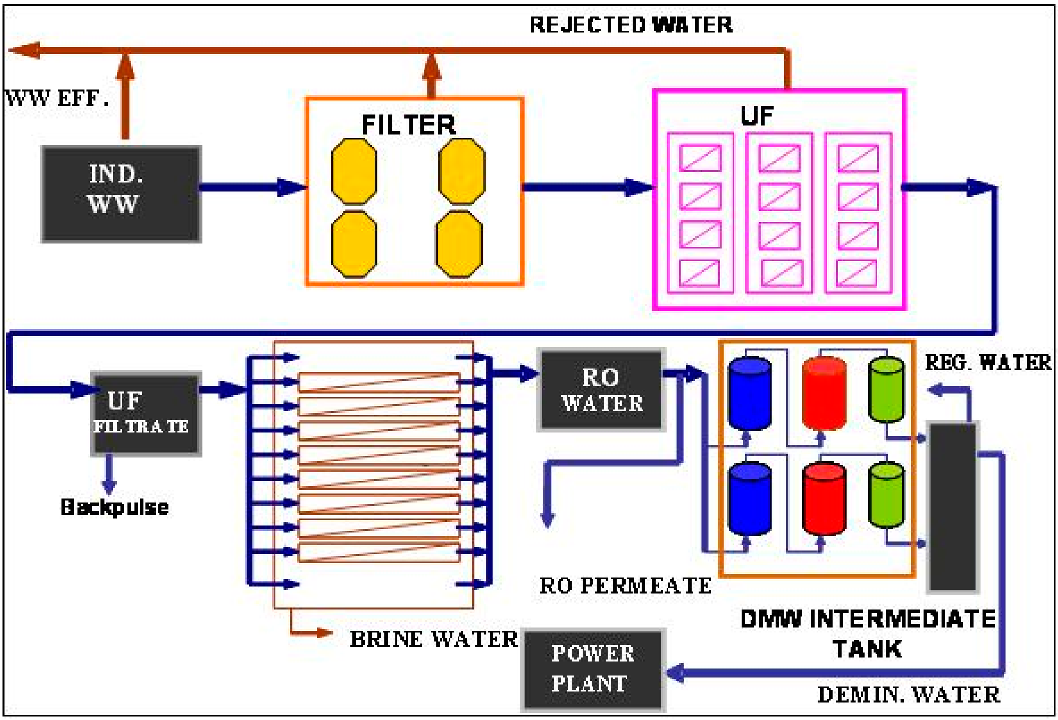


Figure 10.2.1 Treatment Process Schematic Diagram of IWWPP

Dimensions of the plant

The IWWPP is a four-floor steel structure building. The building site area is about 22m wide and 80m long. There are two UF tanks and two RO tanks and each tank capacity is 150m^3. The total capacity of the three demineralised water tanks is 3,000m^3. The capacity of the neutralisation tank is 320m^3.

Product water characteristics

There are two products from the IWWPP. One is RO-water and the other is demineralised water. In the RO system, the filtration water from the UF system is pumped with high pressure through the RO membrane to the clear water zone. The output characteristics of the RO water plant are as shown the table below.

The ion exchanger system is designed to treat the RO product water with cation exchangers, anion exchangers and mixed bed exchangers. The characteristics of demineralised water of the ion exchange process are also shown below.

Through efforts made over more than six years, this reclaimed water plant is set up not only to introduce a new water resource producing high quality water, but also to reduce the load on the environment. It is genuine "garbage turned into gold".

Conductivity	250 µS/cm
Ca-Hardness	10 mg/l as $CaCO_3$
Mg-Hardness	2 mg/l as $CaCO_3$
Silica	1.0 mg/l
Na^+	30 mg/l
COD	10 mg/l
Cl^-	30 mg/l

Table 10.2.2 The permeate characteristics of the RO system

Conductivity	0.1 µS/cm average
Conductivity	0.2 µS/cm end point
Silica	0.01 mg/l as SiO_2 average
Silica	0.02 mg/l as SiO_2 end point
Na^+	0.01 mg/l average
Na^+	0.02 mg/l end point
Cu^{++}	5 µg/l as Cu
Fe^{++}	10 µg/l as Fe

Table 10.2.3 The demineralised water characteristics of the ion exchanger system

10.3 Tenaris Dalmine - Combined water system

The centralised water system supplies:

- 3 hot rolling mills (FTM, FAS, FAPI)
- 1 steel plant (FACC)
- 1 power plant (CTE).

The water is used as direct cooling water (hot rolling processes, continuous casting) and indirect cooling water (furnaces, EAF, power plant).

The main source of water is groundwater so no pre-treatment is needed.

Post-treatment

Direct cooling water (three systems: FTM, FAS+FAPI and FACC)

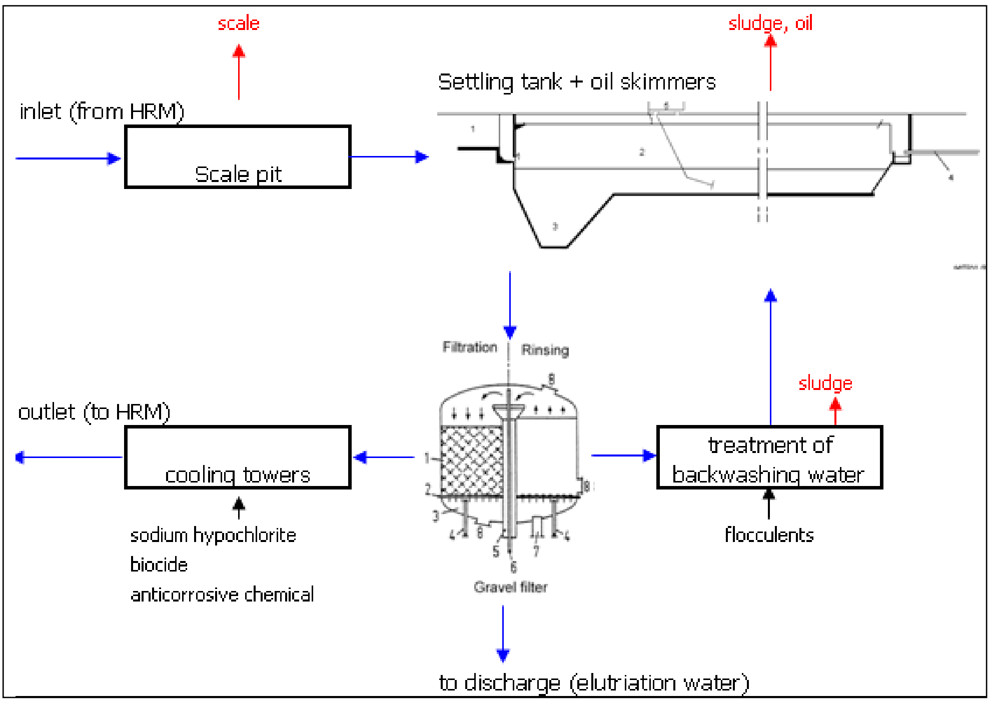


Figure 10.3.1 Post-teatment direct cooling water system Tenaris Dalmine

For continuous casting and other direct cooling water of the steel plant, the system is less complex, with just sand filters and cooling towers.

Indirect cooling water (three systems: FTM, FAS+FAPI and steel plant)

In this case the only treatment applied is cooling towers step (with chemicals added).

The blow-down water (to avoid salt build-up) from each system is collected by FAS+FAPI system direct cooling water. Due to the large amount of water recirculated in this system, these flows can be diluted and reused. In heavy rain, a discharge from this system to the river can be activated.

Amounts treated

FAS+FAPI system (direct and indirect cooling water):	~ 4,800 m^3/h
FACC system (direct and indirect cooling water):	~ 4,500 m^3/h
FTM system (direct and indirect cooling water):	~ 4,500 m^3/h

Quality of treated water

SS	< 80mg/l
THC	< 5mg/l
Fe	< 2mg/l
COD	< 160mg/l

Chemicals used

- flocculants (organic polyelectrolyte)
- sodium hypochlorite
- biocide
- anticorrosive agent.

Waste generated

- scales: ~ 20.000 tonnes/y
- sludge: ~ 8.000 tonnes/y
- oil: the specific stream coming from treatment plants is unknown.

10.4 Tata Steel IJmuiden – Demineralisation

In the demineralisation plant river water is softened and desalinated to produce water that can be used in all kinds of installations, for example as make-up water in boilers.

To produce three different types of 'demin water' a process of lime softening and ion exchange is applied (see flow diagram below).

The plant uses 4.5 to 5.0 million m^3 a year of river water to produce approximately 4.0 million m^3/year demin water. The capacity of the plant for the three types of demin water is 400m^3/h of G-water, 350m^3/h A-water and 350m^3/h of M-water (see below for definitions).

Description

The first step in the process is water softening. Preheated water (15-25°C) is mixed with powdered lime ($CaOH_2$), iron sulphate ($FeSO_4$) and a flocculant. In an accelator a major part of the salts and solids settle and are removed from the water. The sludge is dewatered with a centrifuge and transported to the sinter plant for reuse.

The second step, the actual demineralisation, consists of sand filtration and ion exchange through kation-, anion- and mixed-bed filters. The water that has gone through the sand filters only is called G-water; a better quality of water after cation and anion is known as A-water and the best quality is coming from the mixed-bed filter and called M-water. More information about the characteristics of these types of water can be found in the table below.

The mixed-bed filters are filled with anion and cation resins to remove the remaining small amounts of cations and anions. After sand filtration, condensate coming from other installations is also treated in the mixed-bed filters. Before the M-water is distributed to customers some ammonia is added to the water (0.5mg/l NH_3).

Wastewater

Rinsing water and regeneration fluids are neutralised before discharge to surface water. NaOH and HCl are added for this purpose. Both chemicals are also applied as regenerants for the ion exchangers. The composition of the wastewater after neutralisation is shown in the table below.

M-water		G-water		A-water	
SiO_2	< 0.02 mg/l	Hardness - total	1.5 mmol/l	SiO_2	<0.1 mg/l
Chloride	< 0.02 mg/l	pH	ca. 10	Chloride	ca. 2 mg/l
Ammonia	0.5 mg/l			Sodium	ca. 2.5 mg/l
pH	ca. 9			pH	ca. 9
Conductivity	1-3 µS/cm			Conductivity	1.5 µS/cm

Tabie 10.4.1 Some characteristics of the different types of demin water

Flow	820 m^3/d			Cr	0.015 mg/l
COD	45 mg/l	Cd	<0.005 mg/l	Cu	0.035 mg/l
TKN	3 mg/l	Hg	<0.0001 mg/l	Pb	0.001 mg/l
		As	0.001 mg/l	Ni	0.015 mg/l
				Zn	0.02 mg/l

Tabie 10.4.2 Wastewater composition

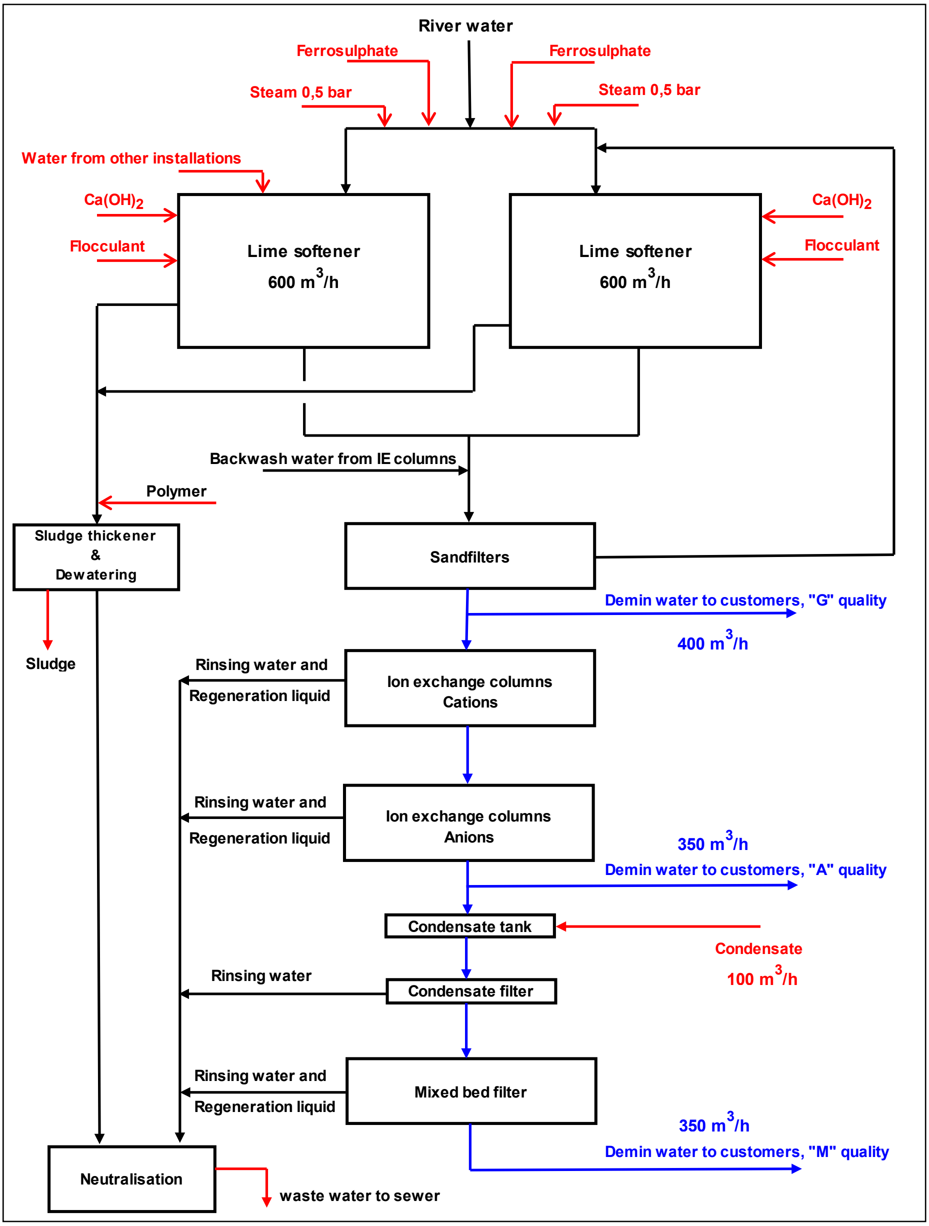


Figure 10.4.1 The demin plant of Tata Steel IJmuiden

10.5 Tata Steel IJmuiden – Central Waste Department

All waste from the IJmuiden site are handled by one department. The main concern is to get handling costs as low as possible, within the limits set by legislation and regulations.

With steel production of 7.5 million tonnes/year, about 3.5 million tonnes/year of waste is produced. Treatment methods for this waste are based the following principles:

a. prevention
b. recycling
c. upgrading of the quality
d. end treatment (separation, incineration, dumping).

The result is that 2.0 million tonnes/year can be classified as by-products, i.e. blast furnace slag, steel slag, benzene toluene xylene (BTX) and coal tar from the coke plants.

Another 1.3 million tonnes is recycled or reused in the sinter plant, coke plant (spilled coal, coke and tar) or as waste oil and oil-water emulsions that are handled in an oil treatment plant and emulsion splitting centre at the Central Waste Department.

A part of the waste that is reused, approximately 60,000 tonnes/year, is separately treated in a regeneration plant. Here mixing of solid waste and sludges with >15% water takes place with the addition of coal fines, lime and dry dust.

Handling waste oil and oil-water emulsions

Waste oil and emulsions are collected from about 60 sources on site (60,000 tonnes/year) and another 30 locations outside Tata IJmuiden (10,000 tonnes/year).

In the oil treatment plant oil and water are separated by settling and/or distillation. The oil itself is used as fuel in the blast furnaces. The water is further treated in a biological treatment plant (see figure below).

After settling and skimming, oil-water emulsions are separated in membrane filtration units in the emulsion splitting centre. Water (in this case called permeate) and oil follow the same route as in the oil treatment plant.

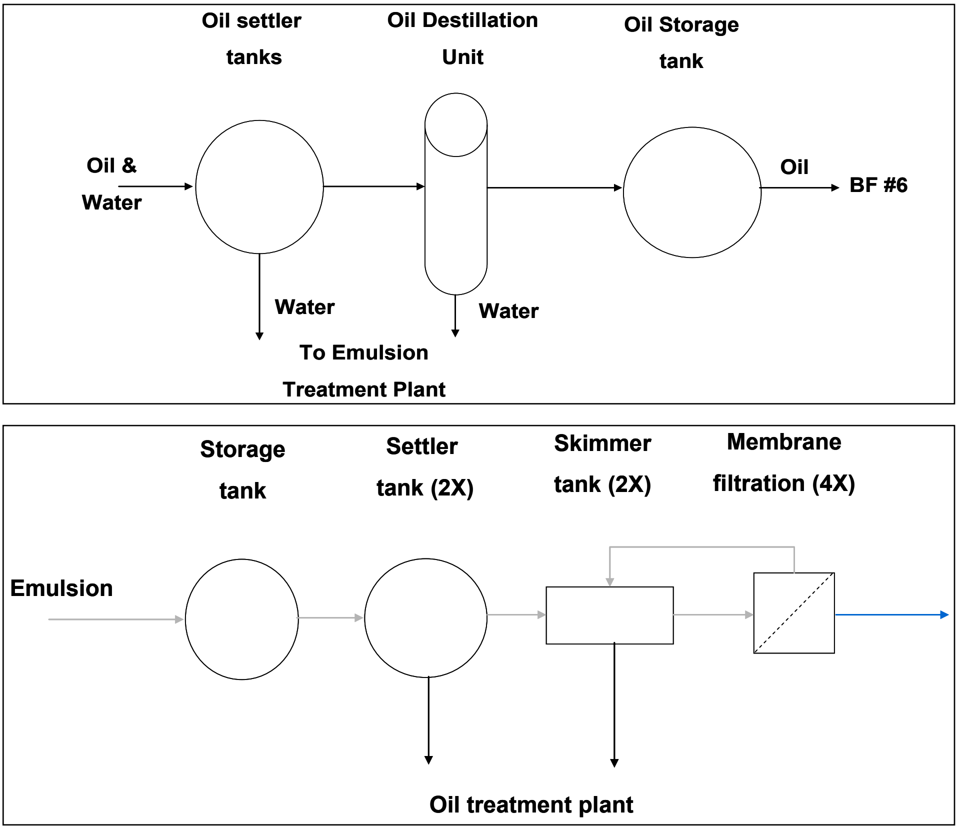


Figure 10.5.1 Oil treatment plant (above) and Emulsion splitting centre (below)

Biological treatment of wastewater

Besides the wastewater from treating the oil and emulsions, domestic wastewater (sewage) from the site and wastewater from Cold Mill No. 1 (cleaning sections) are also handled in a biological treatment plant. Activated sludge in a carrousel-type installation takes care of biological oxidation of the organic materials and nitrification and denitrification of Kjeldahl-nitrogen (KjN) present in these wastewaters.

Influent and effluent amounts and composition of this plant can be found in the tables below.

	Average flow [m³/h]	Average COD [mg/l]	Average KjN [mg/l]
Permeate	10	4,400	75
Regeneration plant	10	480	35
Sewage water	25	170	35
Cleaning sections			
Cold mill	25	1,875	1
Total	70	1,850	35

Table 10.5.1 Influent flows: Biological treatment plant

Component	Average according to permit (mg/l)	Maximum according to permit (mg/l)	Actual results 2007 [mg/l]
COD	150	300	51
TSS	30	80	8
Total N	10		8
Total PO_4	2		0.7
Hg		.0.0005	0.0001
As		0.01	.004
Zn+Cr+Cu+Ni+Pb	0.3	0.5	0.4
EOX		0.1	0.1
Flow in m^3/d		4000	2000

Table 10.5.2 Composition effluent: Biological treatment plant

Appendix B: European best available techniques (BAT)

The EU's integrated pollution prevention and control (IPPC) directive operates under its pollution prevention and control regulations. It is made effective by granting permits to industrial installations.

The directive introduces a number of new terms, like 'best available techniques' (BAT), 'BAT reference document' (BREF) and 'level playing field' (imposing equal demands on like installations within the EU).

To obtain a permit, a company has to demonstrate in its application, in a systematic way, that the techniques it uses represent the use of BATs taking into account relevant local factors, and meet other relevant statutory requirements (Environment Agency, 2004).

BAT-AEL stands for 'best available techniques – achievable emission levels'.

The source of the diagrams in this appendix is the European IPPC Bureau.

BATs relating to coke plant wastewater treatment

Removing tar (and PAH) from still effluent

Ammonia-still effluent normally contains no tar. However, when it does, this tar has an adverse effect on the operation of biological wastewater treatment. In particular, the presence of polycyclic aromatic hydrocarbons (PAH) in the tar may cause problems as the PAH may have a toxic effect on the micro-organisms in the activated sludge.

PAH are relatively difficult to degrade. Therefore, it is advisable to remove tar from the coal water prior to the biological treatment of the water. The tar can be removed by adding coagulating chemicals and subsequent separation using a technique such as:

- gravitational sedimentation sometimes followed by filtration
- centrifuging the coal water
- flotation
- sand filtration.

This treatment removes most of the tar from the wastewater in the form of a highly concentrated filter cake or sludge which has to be treated further, for example by recycling to the coke ovens.

Achieved environmental benefits

With sand filtration effluent concentrations of less than 700 - 800μg/l (EPA-PAH) at a removal efficiency of 99% can be achieved.

Cross-media effects

All of these tar removal techniques generate waste. However, this tar-laden waste, including tar decanter sludge, can be recycled in coke ovens.

Applicability

Removal of tar prior to wastewater treatment is applicable at new and existing plants.

Example plants

Sedimentation and filtration: coke oven, Tata Steel IJmuiden, the Netherlands.

Stripping ammonia from the wastewater

Keeping the concentration of ammonia in the stripper and keeping still effluent low benefits the operation of a biological wastewater treatment plant. The removal efficiency greatly depends on the alkaline and steam addition and on the design of the stripper (the number of stages). A larger dose of NaOH and an increase in the number of stages can significantly reduce the ammonia concentration in the effluent.

When plant effluent treatment involves nitrification and subsequent denitrification, ammonia stripping of the effluent is less critical. In this case, an economic and environmental optimum between ammonia stripping and ammonia removal in the biological wastewater treatment plant should be found.

Achieved environmental benefits

Effluent ammonia concentrations may vary from 20 to 150mg/l, depending on steam and alkali dosage and stripper design. Values of between 20 and 40mg/l are achievable but may not be required because of adjustment of an appropriate balance of BOD5/P/N ratio in the wastewater prior to biological treatment.

Cross-media effects

Strippers consume energy in the form of steam (0.1 - 0.2t steam/m^3 wastewater) and consume alkalis (NaOH; 6 - 22l/m^3). Formerly, lime was used instead of NaOH. Higher doses of steam and alkalis lead to lower NH_3 concentrations in the effluent. Furthermore, an ammonia (and H_2S) laden steam is generated, which must be treated, for example in a sulphuric acid plant, a Claus plant, or in ammonium sulphate crystallisation units.

Applicability

Applicable at new and existing plants.

Economics

Ammonia stripper, treating 150m^3 effluent/hour:

- investments: €750,000 - €900,000 in 1993 for the columns
- operational costs: €0.18/m^3 in 1993.

For an ammonia stripper treating 120m^3 of effluent/hour, the investment costs were €800,000 in 2005 as reported for a plant in Spain (ArcelorMittal, Avilés, Spain).

Example plants

Almost all coke oven plants use an ammonia stripper.

Wastewater treatment

The wastewater from a coke oven plant contains a mixture of hydrocarbons, cyanide compounds and nitrogen compounds in relatively high concentrations. Several methods are available to treat this wastewater. In all cases, it goes through an ammonia stripper before further treatment.

The wastewater can be treated biologically and chemically. With biological treatment, tar is often removed by a physico-chemical process and the wastewater is often diluted to avoid the influents having toxic effects on the micro-organisms, especially the inhibition of nitrifying bacteria.

The most commonly applied biological technique for the treatment of coke oven wastewater is the aerobic, biological system with activated sludge. In some cases, special attention has been paid to nitrification and (anoxic) denitrification. In some other cases, a biological system based on a fluidised bed is used to treat the wastewater.

Techniques included and further described in this section are:

a. an aerobic system with activated sludge
b. nitrification
c. nitrification-denitrification.

a) an aerobic system with activated sludge

In an aerobic system with activated sludge, the biodegradable contaminants are mainly biologically degraded to CO_2, H_2O and minerals. The non-degradable, non-polar components (like most PAH and heavy metals) are removed from the water phase by partial adsorption to the activated sludge. In practice, most of the potentially hazardous contaminants, such as phenols, cyanides and aromatic hydrocarbons, are biologically degraded and heavy metals are partially removed by adsorption to the activated sludge.

Activated sludge systems with a low food/micro-organism ratio (F/M) are preferred from an environmental point of view. A low F/M ratio enables also biodegradation of heavily biodegradable organic compounds. The F/M ratio is the ratio of organic matter to activated sludge as mixed-liquor suspended solids (MLSS) and it is expressed as 'kg COD/kg MLSS/d'; in which COD is the chemical oxygen demand.

Aeration may use oxygen instead of ambient air. This increases process control and reduces 'stripping' of volatile components in the wastewater. Oxygen aeration is used at ArcelorMittal Ghent, Belgium.

b) nitrification

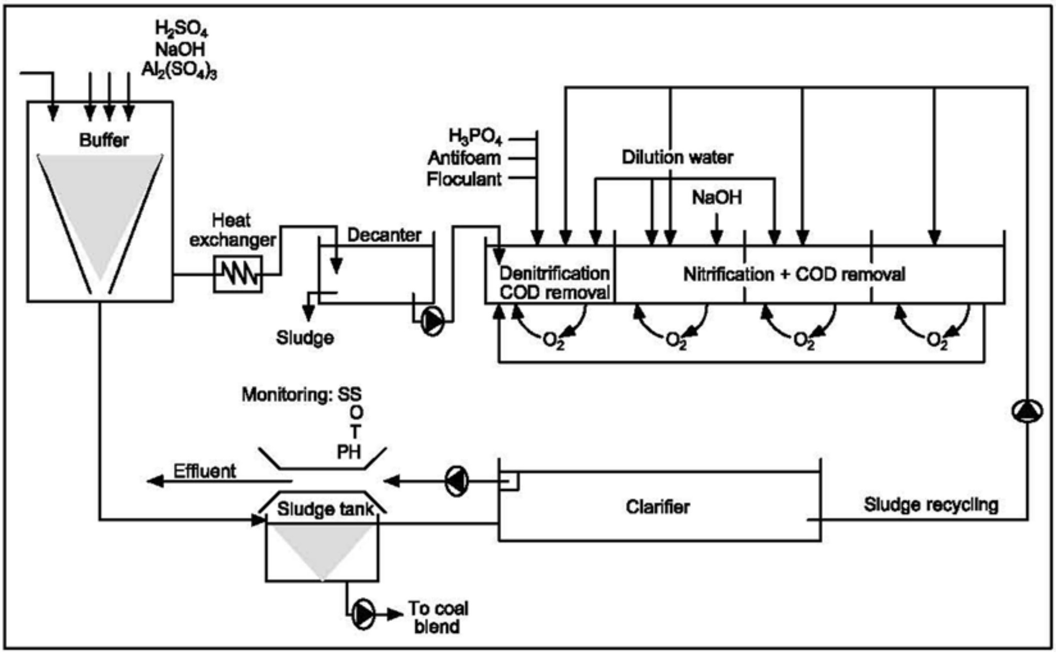
Some wastewater treatment plants are designed to remove ammonium (NH_4^+) efficiently by means of nitrification. The traditional design of an aerobically-activated sludge system can be taken as a starting point for this kind of plant. The system should have a very low F/M ratio and a high recirculation rate in order to avoid the slow growing nitrification bacteria being washed out.

The nitrification bacteria convert the ammonium into nitrate (NO_3^-). Under such conditions, heavily biodegradable organic compounds can also be mineralised with a high removal efficiency.

c) nitrification-denitrification

In some cases, local authorities have demanded low discharges of all nitrogen compounds (including nitrates) from the effluent. This requires additional anoxic treatment of the wastewater.

Several plant layouts are possible, but good results have been obtained at wastewater treatment plants with the pre-denitrification-nitrification concept (pre-DN/N). Two examples are given on the following pages.



Example of a typical biological wastewater treatment with nitrification/denitrification steps

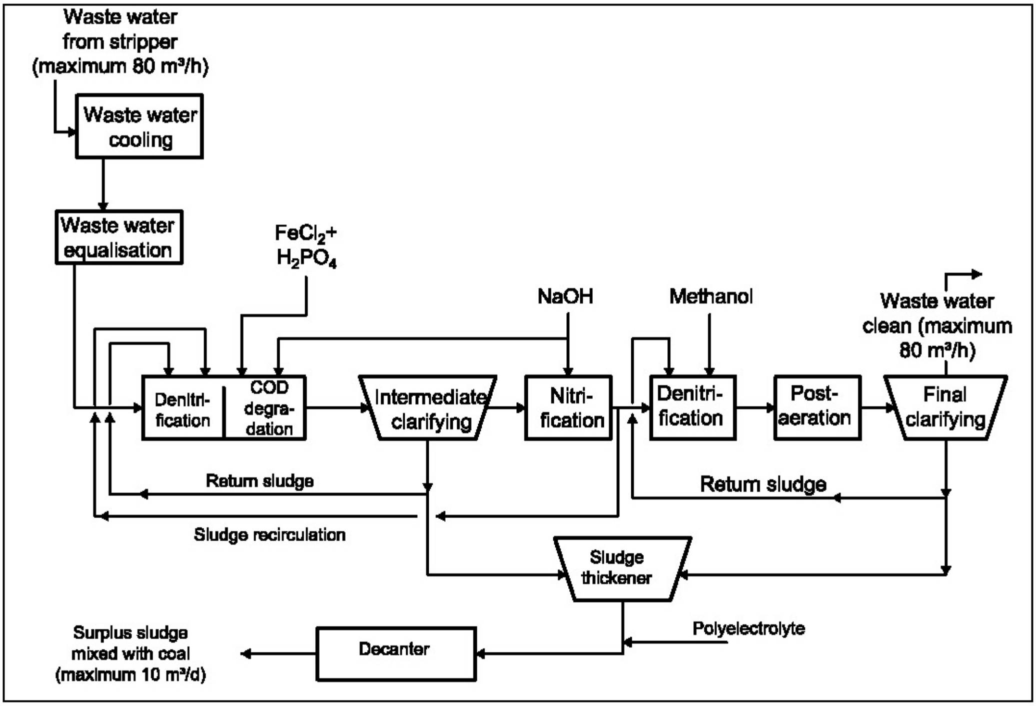
In the pre-DN/N concept, the aerobically-activated sludge system is also used as a starting point. However, before the wastewater is aerated, nitrate-rich water from the nitrification step is added. Under anoxic conditions, bacteria use the nitrate as terminal electron acceptors instead of molecular oxygen (O_2). The nitrogen is emitted as molecular nitrogen (N_2). The overall reaction is:

$$5\ C_{organic} + 2\ H_2O + 4\ NO_3^- \rightarrow 2\ N_2 + 4\ OH^- + 5\ CO_2$$

The wastewater treatment plant (WWTP) of Hüttenwerke Krupp Mannesmann in Duisburg, Germany is designed as a multi-stage biological system, made up of (according to the water flow):

- a heat exchanger to cool down the aqueous effluent from the H_2S/NH_3 stripping column
- an equalisation basin
- an aeration basin (activated sludge process for the degradation of the organic content) with a pre-installed denitrification part as a first denitrification step
- an intermediate clarifier
- a nitrification basin, designed as carrier biology
- a second denitrification step, with methanol feed as the external carbon source
- a post-aeration basin, to resaturate the activated sludge
- a final clarifier.

To monitor the quality of the biologically purified wastewater, the monitoring and control equipment includes online monitoring to alert the operators of irregular conditions early.



Example of a biological treatment plant

This plant shows very good results with the purification of coke oven wastewater by very low emissions of nitrogen, sulphur and cyanide compounds. Influent and effluent concentrations are given below.

In the second draft of the BREF, April 2010, the example of the BIO2000 biological treatment plant of Tata Steel IJmuiden is presented.

Other techniques to remove suspended solids like flotation and sandfilters or wastewater treatment in combination with domestic wastewater can be an alternative, with prerequisites.

Achieved environmental benefits

a) aerobic system with activated sludge

The table below gives the performance figures for aerobically-activated sludge systems from European coke oven plants.

Component	Concentration	Unit	Specific emission value	Unit
COD	140 – 700	mg/l	0.2 – 1	(kg/t coke)
TOC	37	mg/l		
N-Kjeldahl	20 – 120	mg/l	0.01 – 0.1	(kg/t coke)
NH_3	<1 – 100	mg/l	0 – 0.1	(kg/t coke)
SCN^-	<0.1 – 35	mg/l	0 – 0.05	(kg/t coke)
Cyanides, easily released	<0.1	mg/l		
Phenol	<0.1 – 10	mg/l	0 – 0.005	(kg/t coke)
PAH	0.003 – 0.2	mg/l	0 – 0.001	(kg/t coke)

Effluent concentrations and specific emissions from European coke oven plants using aerobically-activated sludge wastewater treatment

b) nitrification

Generally, systems with a low specific load perform better and allow the degradation of ammonia by means of nitrification. A low specific load also enhances the degradation of organic compounds with a low degradation rate. If nitrification is applied, the effluent nitrate (NO_3^-) concentrations will be relatively high (in the order of 200mg/l).

c) nitrification-denitrification

Nitrification-denitrification systems have a very low F/M ratio (0.05 - 0.2kg COD/kg MLSS/d) and achieve very good results in cleaning coke oven wastewater. Nitrogen emissions from these systems are especially low compared to systems with high F/M ratios or with nitrification alone. Influent and effluent concentrations at four of these plants are given in the table on page 131.

Cross-media effects

Activated sludge occurs from the wastewater treatment plant. The surplus activated sludge can be added to the coal feed of the coke oven plant.

Operational data

a) aerobic system with activated sludge

Phosphate and caustic soda are added. Caustic soda is used for pH adjustment. Sedimentation is enhanced by the addition of $FeCl_3$ and a polymer. Although some plants do not need to make any of these additions and achieve good results.

Applicability

To obtain optimum results, an appropriate treatment will use pre-denitrification-nitrification (pre-DN/N) as described under c) above.

Economics

c) nitrification-denitrification

- investment: €600,000 million in 1994 for an extension of a nitrification system to a pre- DN/N-system. Total investments were €4.6 million
- operational costs: were €345,000 a year, including wastewater levies calculated in 1996 (€0.57/t coke).

Driving force for implementation

The demand for low discharges of nitrogen compounds requires a suitable wastewater treatment system.

Example plants

a) Aerobic system with activated sludge

SSAB Tunnplåt AB, Luleå Works, Sweden

c) nitrification-denitrification

Coke oven wastewater treatment plants using the pre-DN/N concept have been installed at ArcelorMittal, Ghent, Belgium; ArcelorMittal, Seremange, France; ZKS, Dillingen, Germany; Hüttenwerke Krupp Mannesmann, Duisburg-Huckingen, Germany.

A coke oven wastewater treatment plant that uses the final additional stripping of ammonia is installed at Rivagroup, Taranto, Italy.

Table on facing page: Influent and effluent concentrations and some aspects of wastewater treatment systems with the pre-denitrification-nitrification system at four plants

Table footnotes:

n/a: not available
All values are arithmetic averages ± standard deviation, if available.
(1) In the first three stages.
(2) Ranges reflect daily averages for the effluent in 2005 except SCN where the 2004 value has been used
(3) BTX
(4) Ranges reflect the mean of the annual averages for the effluent in 2006, 2008 and 2009
(5) Ranges reflect the mean of the annual averages for the effluent in 2009
TNb: total nitrogen bound.

Aspect/parameter	Unit	Plant A	Plant B(5)	Plant C	Plant D(2)
Coke production	Mt/yr	1.25	0.60	1.03	1.08
Coal water flow (surplus water)	m^3/h	42	22	65	80
Dilution by other wastewaters	m^3/h	40	5-10	20	-
Total flow	m^3/h	86	30.1±3.5	85	80
Specific effluent flow (specific wastewater amount)	m^3/t coke	0.59	0.44	0.69	0.65
Food/microorganism (F/M) ratio	kg COD/kg MLSS/d	≤0.15	n/a	0.5(1)	n/a
Influent:					
pH	-	n/a	9.2±0.33	9.0 – 9.5	8.5
Suspended solids	mg/l	30 – 40	33±21	n/a	n/a
COD	mg/l	3650±310	3161±1269	3220±590	200 – 2000
TOC	mg/l	n/a	n/a	1025±190	n/a
BOD5	mg/l	2100	n/a	n/a	800 – 3000
Phenol	mg/l	964	705±276	650	500 – 1500
SCN^-	mg/l	355	n/a	350	150 – 200
N-Kjeldahl-N	mg/l	n/a	n/a	300	n/a
Ammonia-N	mg/l	125±25	n/a	50±15	150±200
Nitrite-N	mg/l	n/a	n/a	n/a	n/a
Nitrate-N	mg/l	n/a	n/a	n/a	n/a
Oil and tar	mg/l	40	n/a	n/a	n/a
PAH (6 Borneff)	µg/l	200	n/a	n/a	n/a
Effluent:					
pH	-	7.7	n/a	7.6	8.1±0.3
Suspended solids	mg/l	42	n/a	75	n/a
COD	mg/l	189±30	137±43	213±70	74±10
TOC	mg/l	n/a	n/a	45±16	n/a
BOD5	mg/l	8.1±2.3	n/a	15±5	4.8±1.7
Phenol	mg/l	0.06	0.02±0.03	<0.1	0.02±0.01
SCN^-	mg/l	3	n/a	1.3	0.87±0.46
CN^-, easily released	mg/l	n/a	0.01	n/a	0.02±0.01
Sulphides, volatile	mg/l	n/a	n/a	n/a	0.03±0.02
N-Kjeldahl-N	mg/l	8.8±4(4)	n/a	n/a	4.96±1.33
TNb-N	mg/l	n/a	n/a	13	10.67±7.04
Ammonia-N	mg/l	3±3(4)	0.28±0.56	<1	<1
Nitrite-N	mg/l	0.9±1.5(4)	0	1.3	0.01±0.07
Nitrate-N	mg/l	22±6.6(4)	8.2±6.92	11	6.11±6.68
Oil and tar	mg/l	5	n/a	n/a	<5(3)
PAH (6 Borneff)	µg/l	<50	n/a	<20	1.06±1.12
Phosphorus	mg/l	n/a	0.4±0.29	n/a	1.3±0.4

Conclusions

- BAT is to minimise and reuse quenching water as much as possible
- BAT is to avoid the reuse of process water with a significant organic load (like raw coke oven wastewater, wastewater with a high content of hydrocarbons, etc.) as quenching water.

Wastewater pre-treatment

For wastewater from the coking process and coke oven gas (COG) cleaning, BAT is to pretreat it prior to discharge to a wastewater treatment plant by applying the following techniques individually or in combination:

I. using efficient tar and PAH removal by using flocculation and subsequent flotation, sedimentation and filtration individually or in combination
II. using efficient ammonia stripping by using alkaline and steam.

Wastewater treatment

For pretreated wastewater from the coking process and COG cleaning, BAT is to apply biological wastewater treatment with integrated denitrification/nitrification stages.

The BAT-AELs are:

- COD <220mg/l
- BOD_5 <20mg/l
- sulphides (volatile) <0.1mg/l
- SCN^- <4mg/l
- CN^- (easily released) <0.1mg/l
- PAH (6 Borneff) <0.05mg/l
- phenols <0.5mg/l
- sum of NH_4^+-N, NO_3^--N and NO_2^--N <15 – 50mg/l.

Regarding the sum of NH_4^+-N, NO_3^--N and NO_2^--N, values of <35mg/l are usually associated with the application of advanced biological WWTPs with pre-denitrification/nitrification and post-nitrification.

The BAT-AELs are based on a qualified random sample or a 24-hour composite sample. These values refer only to single coke oven water treatment plants.

BATs relating to blast furnace cooling and gas cleaning

Treatment and reuse of scrubbing water

BF gas is usually cleaned in specially designed hurdle type venturi or annular gap scrubbers. This generates a contaminated water flow which contains suspended solids (1 - 10 kg/t hot metal), heavy metals, cyanides and phenols. Measures can be taken to minimise discharges to water and to minimise water use.

To scrub the pollutants from the BF gas, approximately 0.3 - 4.0l/Nm^3 are needed. This figure corresponds to a gross water consumption of 0.4 - 8m^3/t hot metal. A large part of this water can be treated and recycled.

The treatment is usually performed in circular settling tanks. The sedimentation properties of the sludge are very often improved by dosage of flocculation agents (anionic polyelectrolytes, mixed polymers or activated silicic acids) or by sludge contact plants. Attention must be paid to pH value and water hardness.

The overflow of the sedimentation step is usually taken to a cooling device (e.g. cooling tower) to adjust the water temperature and then taken back to the scrubbing unit for further reuse. Freshwater is added after the cooling devices, to avoid an enrichment of dissolved matter.

Operational data from seven German sludge contact plants for the treatment of scrubbing water can be seen in the table below.

Plant No.	BF gas flow	Water flow	Content of suspended solids in (mg/l)		Flocculation type	Agent dosage (mg/l)	Sludge water content (%)	Electricity use (kWh/ 1000m^3)
	(103 Nm^3/h)	(m^3/h)	before treatment	after treatment				
1	50	225 – 375	1,000 – 3,000	10 – 50	Activated silicic acid	5 – 10	60 – 85	40
2	250	1,500	500	50	Mixed polymer	0.4	85 – 90	17.8
3	55	500	300 – 600	20	Activated silicic acid	6	75 – 85	-
4	550	50	100 – 300	20 – 30	Activated silicic acid	-	85 – 95	8
5	225	1,100	260	10	Anionic polyelectrolyte	0.13	63	27.5
6	320	1,400	430	13	Anionic polyelectrolyte	0.13	60	21.5
7	125	800	150	20	Mixed polymer	10	60	-

Operational data from seven German sludge contact plants for the treatment of scrubbing water

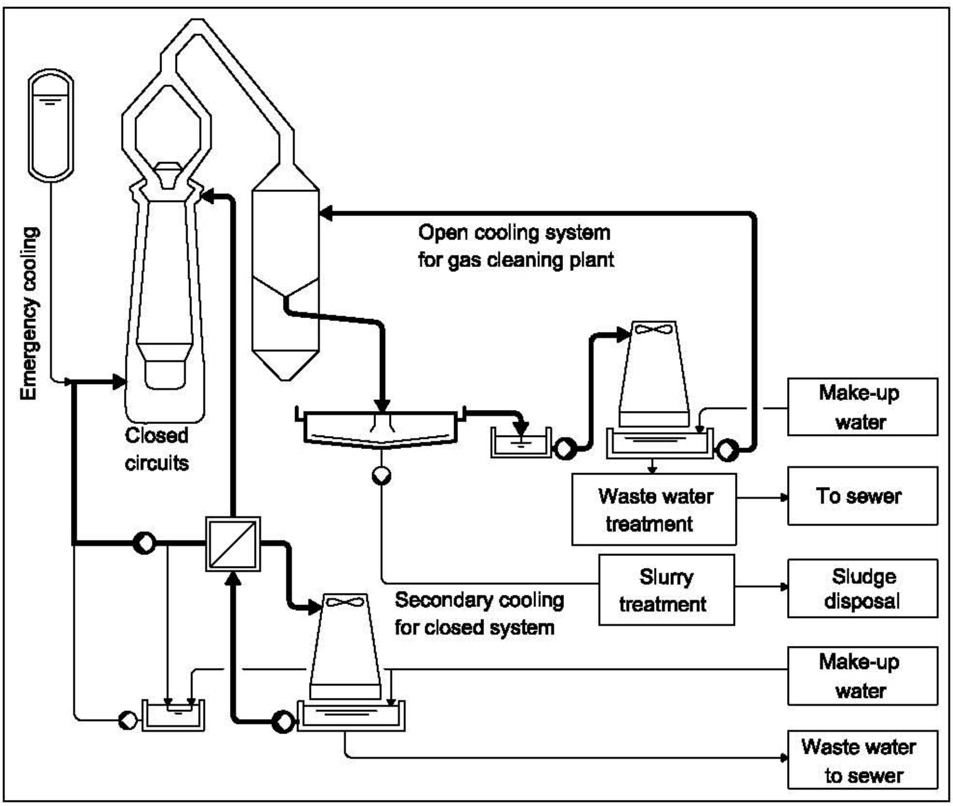
Depending on the operational conditions of the blast furnace, cyanide treatment may be necessary, particularly during blowdown operations. The figure below shows a scheme of the process for the cyanide treatment of scrubbing water at blast furnaces, which is mainly performed by formaldehyde addition to the water circuit before sedimentation. The addition of formaldehyde is continuously controlled by a controlling circuit (redox potential) attached to the water flow before the sedimentation unit.

Long term experience indicates that:

- the optimum pH is between 8 and 9
- there is no reaction below pH 7
- glyconitrile is decomposed at above pH 12 into cyanide and formaldehyde.

In addition to the transformation of cyanide with formaldehyde to form glyconitrile an oxidation of glyconitrile can be performed to lower the environmental impact.

In ArcelorMittal Bremen the discharge water from the scrubbing water circuit is taken to a sedimentation unit for further treatment. The pH is adjusted with a sodium hydroxide solution to pH 10.2 and a hydrogen peroxide solution (H_2O_2) is added to oxidise the glyconitrile to glycol acid. The high pH also ensures an optimal separation of heavy metals in the discharged scrubbing circuit water before it is sent to the recipient.



Example process for the cyanide treatment of scrubbing water at blast furnaces

The sludge from the fine particle precipitation has a relatively high zinc content and can be treated by means of hydrocyclonage.

A new concept of wastewater treatment is used at Tata Steel IJmuiden. It is called BIO 2000 and consists of the combined treatment of wastewater from the coke oven plant, the blast furnaces and from the sinter plant in an activated sludge system with pre-denitrification and nitrification, to minimise COD and nitrogen compounds emissions.

Achieved environmental benefits

High recycling efficiency of the scrubbing water can be achieved with an overflow of only $0.1m^3/t$ hot metal. This water is removed from the system with the blast furnace sludge and may undergo further treatment.

The achieved discharge concentrations for BF gas scrubbing water for a wastewater treatment plant are shown in the table below. The total water demand in 2006 was $719{,}713m^3$. With a hot metal production of 3,152,134 tonnes, this equates to a specific wastewater amount of $0.23m^3/t$ hot metal.

Parameter	Units	No. of measure-ments	Mean value	Median	Max.	Min.	Standard deviation
Cd	µg/l	39	0.36	0.20	3.00	0.20	0.58
Cr	µg/l	39	2.20	2.00	3.90	2.00	0.47
Cu	µg/l	39	9.52	6.10	13.00	2.00	13.75
Fe	µg/l	39	460.77	90.00	3,700.00	13.00	861.79
Ni	µg/l	39	12.93	8.90	39.00	2.00	10.10
PB	µg/l	39	24.93	8.00	390.00	<2.00	62.08
Zn	µg/l	39	354.00	130.00	2,600.00	20.00	582.73
CN	mg/l	39	0.84	0.22	9.80	0.01	2.05
$CN_{easily\ released}$	mg/l	39	0.25	0.04	5.50	0.01	0.89
Cl	mg/l	39	1,000.21	854.00	1,360.00	452.00	414.52
AOX	µg/l	39	37.33	19.00	450.00	10.00	70.13
Suspended solids	mg/l	39	21.91	9.60	166.00	0.60	31.79
DOC	mg/l	39	55.25	54.25	170.00	1.70	40.77
TOC	mg/l	39	55.66	45.00	174.00	2.20	42.06
COD	mg/l	28	144.12	145.50	280.00	<15	69.84
Mineral oil hydrocarbons	mg/l	39	0.16	0.18	0.56	0.10	0.08
Fish egg toxicity		12	6.58	4.00	32.00	1.00	8.16
Note: random sample measurement data from April 2000 to November 2006.							

Discharge concentration for wastewater from the BF gas scrubbing water circuit after treatment at ArcelorMittal, Bremen, Germany

The composition of the BF gas scrubbing water and the achieved discharge concentrations for the aforementioned combined wastewater treatment at Tata Steel IJmuiden is described in the case study on page 59 of this report.

Cross-media effects

When large amounts of water are recirculated, an efficient water treatment system must be used. Otherwise, operational problems will occur affecting the scrubbers (clogging, etc.) and scrubbing efficiency will drop. Water treatment and recycling generates a zinc-rich sludge. A small overflow from the circuit is necessary to avoid the accumulation of minerals and salts.

Scrubbing water recycling requires a significant amount of energy. In addition, the dosage of flocculation agents should be considered.

Applicability

New and existing plants can apply the treatment and recycling of scrubbing water. Modern plants have an advantage because they can be designed with an efficient water circuit. The salt content of the wash water influences the recycling rate. However, it is also possible to install an efficient water circuit in older plants.

Example plants

ArcelorMittal, Bremen, Germany; Tata Steel IJmuiden, the Netherlands

Conclusions

Water consumption and discharge

BAT for wastewater from blast furnace gas treatment is to minimise and to reuse scrubbing water as much as possible, e.g. for slag granulation if necessary after treatment with a gravel-bed filter.

Wastewater treatment

BAT for wastewater from blast furnace gas treatment is to use flocculation (coagulation) and sedimentation and the reduction of easily released cyanide, if necessary.

The BAT-AELs are:

- suspended solids <30mg/l
- iron <5mg/l
- lead <0.5mg/l
- zinc <2mg/l
- cyanide, easily released <0.4mg/l.

The BAT-AELs are based on a qualified random sample or a 24-hour composite sample.

BATs relating to pellet plant gas cleaning

Water flows

Whenever scrubbers are used to remove pollutants, a wastewater flow is generated. This wastewater needs a bleed, due to the presence of hydrofluoric acid (HF). This bleed is relatively small when wastewater recycling and NaOH addition are applied. In some cases, this bleed water is treated in an arsenic removal plant.

In addition, wastewater is discharged from the wet rinsing of the plant and equipment. In the plant at Tata Steel IJmuiden, this water is 100% recycled and this flow is about 0.04m^3/t pellets. Cooling water may derive from the grinding and drying section as well as from the induration strand. For this plant, the specific flow is 0.16m^3/t pellets from grinding and drying and 0.05m^3/t pellets from induration respectively.

For the new MK3 pellet plant in Malmberget, Sweden, the situation is special. Parts of the mine water are used as process water for scrubbers and wet ESPs in the refining stages. The process wastewater, runoff water and mine water enter through a thickener from where the waters are further conducted to a tailing pond where pre-settling takes place. From there, water is led to a clarification pond where additional sedimentation is achieved.

At the Swedish plant, water pollution is continuously measured. The table below shows the achievable concentration values for the plants located in Kiruna and Malmberget, Sweden.

Parameter	Malmberget 2006	Malmberget 2007	Kiruna 2006	Kiruna 2007	Units
	Concentration				
Suspended solids	9.12	10.9	4.13	2.33	mg/l
Total N	39.5	41	19.8	17.5	mg/l
Phosphorus	41.4	48.7	0.039	0.028	µg/l
Cadmium	0.018	0.011	0.025	0.014	µg/l
Cobalt	3.63	6.23	0.35	0.37	µg/l
Chromium	0.70	0.35	0.05	0.1	µg/l
Copper	2.30	3.73	2.68	4.03	µg/l
Mercury	<0.002	<0.002	<0.002	<0.002	µg/l
Lead	0.20	0.14	0.13	0.24	µg/l
Zinc	6.87	5.95	0.63	4.56	µg/l
Nickel	13.7	16	1.83	2.39	µg/l
Arsenic	3.34	1.47	3.56	0.7	µg/l
Sources: Gidlund et al. 2008, Lundqvist, A. 2009					

Operational data from the Malmberget and Kiruna (Sweden) water treatment

Pellet plant water treatment

The wastewater from scrubbers undergoes neutralisation before it enters a circulation basin. From there it is further processed to settling tanks. The sedimentation properties of the sludge are often improved by dosage of flocculation agents. A part of the wastewater from the settler is reused as scrubbing water. At Tata Steel IJmuiden, another part is directed as a bleed to the arsenic removal plant to be further precipitated.

Achieved environmental benefits

Pre-cleaning of process water and separation of sludge enables water recycling in the scrubber.

Cross-media effects

Sludge needs to be recycled or disposed of and may contain heavy metals such as Ni, Cr, and Cd.

Operational data

No specific problems are known.

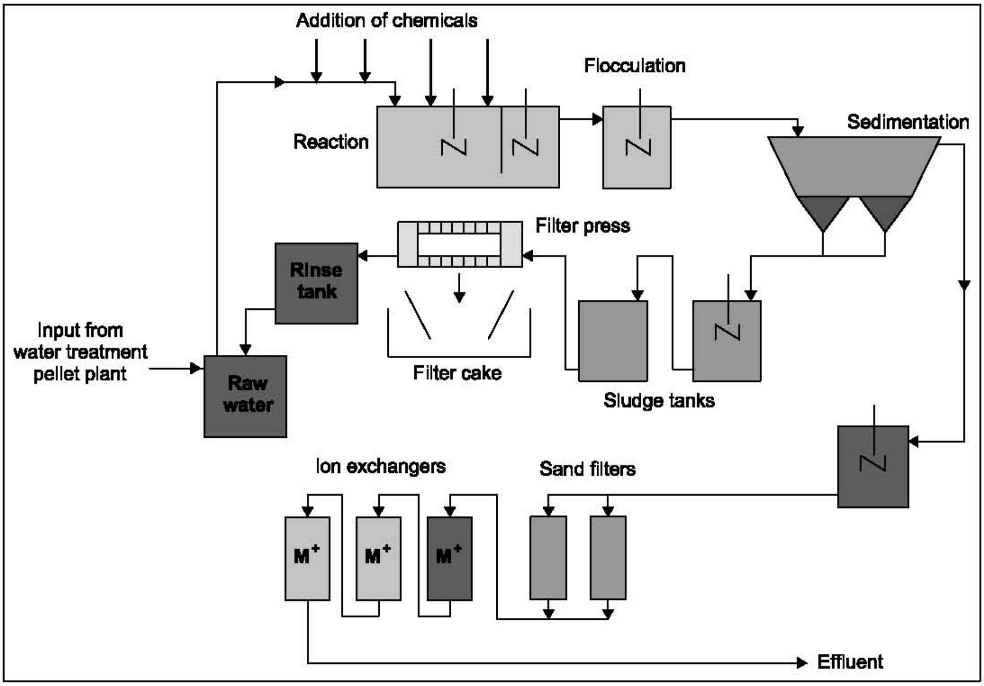
Example plants

Tata Steel IJmuiden, the Netherlands.

Arsenic removal plant

The wastewater from the water treatment plant at the Tata Steel IJmuiden pellet plant contains dissolved arsenate (As^{5+}) and arsenite (As^{3+}). Arsenic compounds are present in some iron ores. The arsenite is converted to arsenate by means of Fenton's reagent (combination of Fe(II) chloride and peroxide) at pH 7, after which the arsenate is precipitated.

After dewatering, the filter cake which contains arsenic can be recycled or disposed of. After sedimentation, the wastewater passes through sand filters to remove residual suspended solids, and three ion exchangers to control the level of other heavy metals, such as Cd, Cr, Cu, Ni (see figure below).



Process flow diagram of an arsenic removal plant

Achieved environmental benefits

The operational data from the arsenic removal plant are shown in the table below.

Parameter	Range	Units
Suspended solids	<10 – 95	mg/l
COD	56 – 81	mg/l
Total Kjeldahl-N	8.1 – 15	mg/l
Flourides	1,300 – 2,000	mg/l
Cd	<1 – 1.7	µg/l
Hg	0.25 – 2	µg/l
As	10 – 27	µg/l
Cr	13 – 18	µg/l
Pb	10 – 83	µg/l
Zn	43 – 95	µg/l
Ni	44 – 64	µg/l
Cu	<1 – 19	µg/l

Operational data from the arsenic removal plant (2007)

Cross-media effects

An arsenic sludge needs to be recycled or disposed of and may contain heavy metals such as Ni, Cr, and Cd.

Operational data

No specific problems are known. Consumption of chemicals has not been reported.

Applicability

The removal of arsenite and arsenate can be implemented as an end-of-pipe solution at all types of new and existing water treatment plants.

Economics

The investment cost for an arsenic removal plant with a capacity of $55m^3/h$ was €2.6 million in 2004. These costs also depend on the effluent limits of arsenic and the heavy metals.

Driving force for implementation

The Tata Steel plant in IJmuiden, the Netherlands is being optimised to comply with legal limits and to reduce operating costs.

Example plants

Tata Steel IJmuiden's arsenic removal plant has been operational since August 2004.

Conclusions

Water consumption

BAT is to minimise water consumption and the discharge of scrubbing, wet rinsing and cooling water and reuse it as much as possible.

Wastewater treatment and discharge

BAT is to treat the effluent water prior to discharge by applying a combination of the following techniques:

I. neutralisation
II. flocculation
III. sedimentation
IV. sand filtration
V. heavy metal precipitation.

The BAT-AELs are:

- suspended solids <50mg/l
- COD <100mg/l
- Kjeldahl nitrogen <10mg/l
- heavy metals <0.2mg/l (Sum of As, Cd, Cr, Cu, Hg, Ni, Pb, Zn).

The BAT-AELs are based on a qualified random sample or a 24-hour composite sample.

Where local considerations make it necessary, BAT is to remove heavy metals by using ion exchangers.

BATs relating to sinter plants

Wastewater

Rinsing water

Processes in an iron and steel plant cause dust deposition on the plant premises. To prevent runoff to surface water, this dust should be removed, preferably by dry techniques.

A few plants, however, use rinsing water. The resulting wastewater contains suspended solids (including heavy metals) and is usually treated before discharge. For example, in a sinter plant with a production of approximately 11,000 tonnes of sinter a day, the rinsing water flow is about $460m^3$/day. This wastewater is treated by sedimentation in the recirculation circuit and enhanced settling prior to discharge.

Cooling water

In the sinter plant, cooling water can be used for the cooling of the ignition hoods and the fans as well as for the sinter machines. In an integrated steelworks producing 4Mt of steel a year, the sinter plant cooling would require a water flow of approximately $600m^3$ per hour. The cooling water is normally completely recycled.

Legal constraints by some local authorities require the prevention of plumes or the formation of industrial snow and ice during winter from re-cooling towers, which might prevent further cooling water recycling.

Wastewater from waste gas treatment

Wastewater from waste gas treatment will only be generated if a wet abatement system is applied. The water flow contains suspended solids (including heavy metals), persistent organic pollutant compounds such as PCDD/F and PCB, PAH, sulphur compounds, fluorides and chlorides. It is usually treated before discharge.

Water treatment

The wastewater from scrubbers undergoes neutralisation before it enters a circulation basin. From there it is further processed to settling tanks. The sedimentation properties of the sludge are often improved by dosage of flocculation agents. A part of the wastewater from the settler is reused as scrubbing water. At Tata Steel IJmuiden, another part is directed as a bleed to the arsenic removal plant to be further precipitated.

Achieved environmental benefits

Pre-cleaning of process water and separation of sludge enables the recycling of water in the scrubber.

Cross-media effects

Sludge needs to be recycled or disposed of and may contain heavy metals such as Ni, Cr, and Cd.

Conclusions

Water consumption

- BAT is to minimise water consumption by the recycling of cooling water as much as possible unless once-through cooling systems are used.
- BAT is to treat the effluent water prior to discharge by applying a combination of the following techniques:
    I. heavy metal precipitation
    II. neutralisation
    III. sand filtration.

This BAT is only relevant when rinsing water is used or when a wet waste gas treatment system is applied.

The BAT-AELs are:

- suspended solids <30mg/l
- COD <100mg/l
- heavy metals <0.1mg/l (Sum of As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn).

The BAT-AELs are based on a qualified random sample or a 24-hour composite sample.

BATs relating to basic oxygen steelmaking and casting

Wastewater

Water is used for the following purposes:

- scrubbing water from BOF gas treatment
- scrubbing water from the wet dedusting of desulphurisation
- water from vacuum generation
- water from direct cooling from continuous or ingot casting.

To optimise the use of wastewater in integrated steelworks, single flows can be mixed and subsequently treated together. In such cases, information about the composition of wastewater from a single production step might not be available.

Wastewater from BOF gas treatment

BOF gas is treated wet or dry. In the case of wet cleaning, wastewater is produced and normally recycled after treatment. This treatment is very often performed in two steps: separation of coarse particles (>200m grain size) followed by sedimentation in circular settling tanks. Flocculating agents are added to improve sedimentation.

The purpose of electrical flocculation is to eliminate small and slowly settling particles by means of an electrical field. Particles with the same polarity tend to repel each other, thus accelerating the sedimentation process. In electrical flocculation, the surface of the particles is charged when passing the electrical field which enables the agglomeration of particles.

The electrical flocculation system consists of several segments that are installed in the middle of the settling tank near the wastewater inlet. Each segment consists of one anode and four cathode pipes. A DC current is conducted from the anode to the cathodes via the wastewater, thus generating an electrical field.

The capacity of settling tanks is remarkably increased and no chemical flocculants are needed. The process also has an anti-scaling effect which prevents the sedimentation of particles on the surfaces of the settling tank.

The sludge is dewatered by means of rotary vacuum filters, chamber filter presses or centrifuges. Representative data about flow and quality of the treated wastewater discharged from the circuit (overflow) are not available.

Wastewater from vacuum generation

For the vacuum treatment, the usual specific process water flow from vacuum generation ranges from 5 – 8m^3/t LS vacuum treated. In a few cases, the specific process water demand is higher; in one case 41m^3/t LS (see table below). This water is almost fully recycled.

It should be noted that not all of the liquid steel has to be vacuum treated. Therefore, the weighted specific overall wastewater output from vacuum treatment is 1.3m^3/t LS.

Data on composition and treatment or recycling are not available. Usually this wastewater is treated together with other streams from the rolling mill(s) in their immediate vicinity.

Wastewater from continuous casting

Emissions to water from continuous casting machines are generated by the direct cooling system. This is used for the direct cooling of slabs, blooms, billets and the machines. The wastewater contains mill scale (1 – 3g/l) and oil/grease. This water is often treated together with wastewater from rolling mills in their direct vicinity. The amount of wastewater depends very much on local conditions and water management. The specific water demand for continuous casting is usually between 5 and 35m^3/t LS. The amount of wastewater which can arise from continuous casting is up to 2m^3/t LS.

Treatment of wastewater from wet dedusting

In most oxygen steelmaking plants, scrubbers are used to reduce emissions to air from the primary gas flow (BOF gas). This potentially transfers pollution from air to water, so the wastewater generated is usually recycled and treated before discharge. The water from the scrubbers mainly contains suspended solids; zinc and lead being the main heavy metals present.

A large part of the suspended solids in the scrubbing water circuit can be removed by means of hydrocyclonage and/or precipitation. After pH correction, most of the water can be recycled. The bleed can be treated by means of precipitation and/or filtration prior to discharge.

Achieved environmental benefits

In the table below, examples are given for the specific emissions to water from wet dedusting systems at oxygen steelmaking plants.

Parameter	Units	Suppressed combustion system		
		Tata Steel IJmuiden, NL (1)	Stelco LEW, Ontario, Canada	LTV Steel, Cleveland Works, USA
Discharge flow	m^3/t LS	0.52	1.1	0.002
Suspended solid	g/t LS	20	5.5	0.0083
Zinc (Zn)	mg/t LS	73	210	0.36
Lead (Pb)	mg/t LS	31	110	0.057
(1) Emissions at Tata Steel IJmuiden, The Netherlands relate to 1994 values. Source: InfoMil 1997				

Examples: specific emissions to water from wet dedusting facilities at oxygen steelmaking plants

The most effective measures for minimising wastewater discharge are:

1. increasing the recirculation rate of the scrubbing water

A high recirculation can be achieved with a two-stage sedimentation process in the scrubbing water flow with carbon dioxide (CO_2) injection prior to the second sedimentation step, to enhance the precipitation of carbonates. Note that the injection of CO_2 is only possible in systems operating suppressed combustion.

2. treating the bleed

Although efficient recirculation can be achieved, a bleed is necessary to avoid the accumulation of certain minerals and salts. The bleed contains suspended solids (including zinc, lead, etc.) as the most important pollutant. The bleed is treated by sedimentation and filtration.

Cross-media effects

Sludge is generated during hydrocyclonage and/or the sedimentation of the suspended solids in the scrubbing water circuit. This sludge can be 100% recycled within the iron and steelmaking process if the zinc input via the scrap is strictly limited, i.e. back to the sintering plant or the BOF after cold briquetting.

At many other steelmaking plants in the world, the sludge cannot be used and is either externally used in the cement making industry or stored or disposed of.

Applicability

A high recirculation efficiency and further treatment can be applied at new and existing plants.

Example plants

Examples for plants with a high degree of recirculation and treatment of bleed are: Tata Steel IJmuiden, the Netherlands; ArcelorMittal, Ghent, Belgium; AlcelorMittal, Cleveland, USA.

Treatment of wastewater from continuous casting

Water is used in continuous casting machines for direct cooling of the slabs, blooms and billets. A contaminated process water flow is therefore generated. In many cases, this wastewater is treated together with wastewater streams from the hot rolling mills. After treatment, the water is recirculated. The casting mould and the inner part of the rollers are usually cooled with water in a closed circuit and are not considered here.

The main pollutants are suspended solids and oil. The main measures to reduce discharges to water are a high rate of recirculation along with sedimentation and/or filtration of the bleed. Skimming tanks can be used to remove oil.

The spray water is commonly precipitated by sand filtration before or after cooling, in an evaporative cooling tower. Sand filtration helps to ensure low levels of particulate and oil contamination to achieve satisfactorily prolonged operation of the secondary spray nozzles of the casting machine.

The bleed from the open circuit to control the level of dissolved solids should be taken from downstream of the sand filtration plant to minimise the discharge of suspended solids and any oil/grease contamination.

To prevent the clogging of the sand filter, oil skimming should be installed before the sand filters.

Achieved environmental benefits

In the table below examples are given for specific emissions to water from continuous casting.

Parameter		Tata Steel IJmuiden, NL (1)	Stelco LEW, Ontario, Canada	ArcelorMittal, Indiana Harbor Works, USA
Discharge flow	(m^3/t cast steel)	0.04	1.4	0.076
Recirculation rate	(%)	98	78	99
Suspended solid	(g/t cast steel)	0.8 0.2(2)	26	1.4
Zinc (Zn)	(mg/t cast steel)	<1	-	8.0
Lead (Pb)	(mg/t cast steel)	<1	-	8.7
Oil	(mg/t cast steel)	20	2,000	160
(1) Data refers to 2004 (2) Data for 2007 indicates a trend downwards Sources: InfoMil 1997, Busink, R. 2009				

Overview of specific emissions to water from direct cooling systemes at continuous casting

Example of the concentration of pollutants in wastewater from continuous casting after treatment at the basic oxygen furnace at ArcelorMittal, Bremen, Germany are given in the table below.

Parameter	No. of measure-ments	Mean value	Median	Max	Min	Standard deviation
Pb (µg/l)	33	3.03	2.00	16.00	<2.00	3.11
Cr (µg/l)	33	2.99	2.00	13.00	<2.00	2.17
Cu (µg/l)	33	6.03	5.70	15.00	0.50	2.74
Zn (µg/l)	33	87.12	62.00	340.00	<20.00	73.89
Cd (µg/l)	33	0.20	0.20	0.27	<0.20	0.01
Fe (mg/l)	33	0.59	0.14	8.50	0.05	1.63
Ni (µg/l)	33	21.88	22.00	37.00	11.00	6.15
$N_{mineral}$ (mg/l)	31	5.09	5.07	7.16	3.29	1.21
AOX (µg/l)	33	41.06	40.00	66.00	21.00	11.00
Suspended solids (mg/l)	33	2.77	1.00	19.00	0.80	4.37
DOC (mg/l)	33	5.31	5.00	10.00	4.30	1.11
TOC (mg/l)	33	5.68	5.40	10.70	4.60	1.22
Mineral oil hydrocarbons (mg/l)	31	0.16	0.18	0.40	<0.10	0.07
Fish egg toxicity	8	1.25	1.00	2.00	1.00	0.43
Note: Random sample measurement data from Feb. 2000 to Nov. 2006 Source: Germany 2007						

Example of the concentration of pollutants in wastewater from continuous casting after treatment at the basic oxygen furnace at ArcelorMittal, Bremen, Germany

Cross-media effects

The sedimentation steps generate a sludge which contains iron which can be recycled into the sinter plant or by direct injection via tuyères in the blast furnace.

Applicability

A high recirculation rate and a treatment of the bleed can be applied at new and existing plants.

Example plants

ArcelorMittal, Indiana Harbor Works, Indiana, USA; Tata Steel IJmuiden, the Netherlands; ArcelorMittal, Ghent, Belgium; Voestalpine Stahl GmbH, Linz, Austria.

Conclusions

Water consumption, treatment and discharge

- BAT is to apply dry BOF gas cleaning where prerequisites are present.
- BAT for wastewater from BOF primary dedusting is to minimise and reuse scrubbing water as much as possible, e.g. for slag granulation.

- BAT is to minimise the wastewater discharge from continuous casting by applying the following techniques in combination:
  I. the removal of solids by flocculation, sedimentation and/or filtration
  II. the removal of oil in skimming tanks or any other effective device
  III. the recirculation of cooling water and water from vacuum generation as much as possible.

The BAT-AELs for wastewater from continuous casting machines are:

- suspended solids <20mg/l
- iron <5mg/l
- zinc <2mg/l
- nickel <0.5mg/l
- total chromium <0.5mg/l
- total hydrocarbons <5mg/l.

The BAT-AELs are based on a qualified random sample or a 24-hour composite sample.

BATs relating to hot-rolling mills

Storage and handling of raw materials and auxiliaries

Oil spillages may occur at storage tanks and from pipelines. Such spillages are drained to pump sumps, from where the oil and grease water mixture may be fed to intermediate waste oil storage tanks. Discharge of filled tanks may be carried out via authorised external companies or, in the case of integrated plant sites, by internal thermal treatment plants or via the blast furnace or coke ovens.

Accidental releases of hydrocarbons are prevented by periodic checks and preventive maintenance of seals, gaskets, pumps and pipelines.

Contaminated drainage water at the various consumers (hydraulic aggregates) should be collected and may be pumped into intermediate storage tanks. The waste oil, after separation from water, should be reused, for example by injection into the blast furnace or by external recycling.

To allow for reuse, the separated oil has to be recovered in sufficient quantities and in a form suitable for reuse; the chemical composition and the physical properties (e.g. viscosity) of the recovered (used) oil have to be the same as of the new oil.

The separated water may be further processed in a water treatment plant, for example with ultra filtration or vacuum evaporator (such as industrial washing machines).

Complete prevention of water and scale contamination by hydrocarbons (oils and grease) is almost impossible even by applying precautionary measures.

Reduction of energy loss through stock transport device

In re-heating furnaces water cooling is used to protect some components and maintain their physical strength. Examples include doors, lintels and the stock transport mechanism or support system.

Water-cooled components represent a significant source of energy loss. In particular, the loss through stock transport systems in continuous (walking beam) furnaces, can account for 6-12% of the fuel input under typical operating conditions. Close to the end of a furnace operating campaign, when insulation of the cooled components begins to degrade, the loss can be as high as 20-25%.

Losses from stock supporting structures can be minimised at the design stage by optimising or reducing the number of cooled beams and supports and by using suitable insulation.

Main achieved environmental benefits

Reductions in water cooling losses of 26.7GJ/h (equivalent to a fuel saving of 44.5GJ/h) were reported.

Applicability

- new furnaces and existing furnaces
- for existing furnaces, optimisation can be done during refractory maintenance.

Cross-media effects

- 46% reduction in water use.
- reduced energy consumption of pusher mechanism
- reduced skid marks, improved quality.

Material tracking

Automation of the respective train areas and peripheral sensors allow exact determination of the entry into and the delivery of the materials from the descaling equipment and allow the operator to open the valves of the pressure-water pipes accordingly. As a result, the water volume can be continuously adjusted to the requirement.

Main achieved environmental benefits

- reduced water consumption
- reduced energy consumption.

Applicability

- roughing, finishing and plate mills
- new and existing hot rolling mills for flat products.

Work roll lubrication system

Rolling oils are supplied to the roll gap via nozzles in order to reduce the friction between material and roll, to lower the drive power requirements, to decrease rolling forces and to improve the surface quality of rolled material.

Main achieved environmental benefits

- Reduced energy consumption by reduced rolling load.
- Reduced roll wear (especially at the strip edge areas) resulting in a longer lifetime of work rolls and reduction of grinding sludge.

Applicability

- finishing stands
- new and existing hot rolling mills for flat products.

Cross-media effects

Contamination of water system with rolling oils.

Reference plants

A large number of plants.

Driving force for implementation

Higher mill productivity and increased pickling rate.

Forced interstand strip cooling

To permit acceleration of the finishing train and still attain a constant finishing temperature, forced interstand cooling of the strip by water sprays or water curtains is employed.

Main achieved environmental benefits

- the formation of scale and oxide fumes is suppressed
- decreased wear rate of the work rolls in succeeding stands and reduced grinding sludge.

Applicability

- between finishing stands
- new and existing hot rolling mills for flat products.

Cross-media effects

Generation of wastewater.

Prevention of hydrocarbon contamination

Reduction of oil and lubricant losses is a preventive measure against the contamination of process waters and the included scale. The use of modern design bearings and bearing seals for work-up and back-up rolls and the installation of leakage indicators in the lubricant lines (pressure monitoring equipment, for example, at hydrostatic bearings) can reduce the hydrocarbon content (oil) of scale and wastewater and reduces the oil consumption by 50-70%.

Contaminated drainage water at the various consumers (hydraulic aggregates) should be collected and can be pumped into intermediate storage tanks. The waste oil, after separation from water, can be used as a reducing agent in the blast furnace or can be recycled off-site. The separated water may be further processed either in the water treatment plant or in dressing plants with ultra filtration or vacuum evaporator.

Main achieved environmental benefits

- prevention of oil (hydrocarbon) contamination of water and scale
- reduced amount of oily scale.

Applicability

New plants and existing plants in case of major revamps (less applicable to older plants).

Good operational practice for roll shops

Use of solvents

- as far as technically acceptable for the degree of cleanliness required, water based degreasing should be applied
- if organic solvents are used, preference should be given to non-chlorinated solvents.

Wastes

- grease removed from roll trunnions is collected and disposed of properly (e.g. by incineration)
- grinding sludge is treated by magnetic separation for recovery of metal particles which are recycled into the steelmaking process
- mineral residues from grinding wheels are deposited in landfills
- steel and iron turnings are recycled into the steelmaking process
- worn grinding wheels are deposited in landfills
- worn rolls which are unsuitable for further reconditioning are recycled into the steelmaking process or returned to the manufacturer
- cooling liquids and cutting emulsions are treated for oil/water separation. Oily residues are disposed of properly (e.g. by incineration)
- wastewater effluents from cooling and degreasing as well as from emulsion separation are recovered by the hot rolling mill water treatment plant.

Main achieved environmental benefits

Reduction of overall environmental impact.

Applicability

New and existing roll shops.

Reduction of water consumption and discharge

Implementation of semi-closed and closed loop water systems, with discharge as low as possible.

Main achieved environmental benefits

Reduction of wastewater and pollutant discharge.

Applicability

In some cases upgrading existing plants from 'wet mills' (once-through) to mills with semi- or closed circuits, may not be possible due to insufficient space being available to accommodate a fully equipped water treatment plant at economically justifiable investment costs.

Cross-media effects

- increased energy consumption and consumption of chemicals.
- waste (sludge) generation.

Closed: Stahlwerke Bremen.

Operational data

The table below shows the emission levels achieved with semi-closed and closed water circuits. For comparison the levels achieved by an open system are also given.

Parameter	Open circuit	Semi-closed circuit	Closed circuit
Suspended solids (SS)	≤40mg/l	≤40mg/l	≤40mg/l
Specific emission of SS	approx. 800g/t	approx. 480g/t	0 – 40g/t
Water consumption	100%	approx. 60%[1]	approx. 5%[1]
COD (O_2)	≤40mg/l	≤40mg/l	≤40mg/l
Specific emission of COD	approx.800 g/t	approx. 480g/t	approx. 38g/t
Hydrocarbons (HC) (related to mineral oil)	≤5mg/l	≤5mg/l	≤5mg/l
Specific emission of HC	approx. 100g/t	approx. 60g/t	approx. 5g/t
Notes: Based on a production of approx. 3.0Mt. Wastewater treatment consisting of a combination of individual measures as described in the following chapter (no detailed information available). [1]Compared with open circuit, absolute values for water consumption depend on the individual plant.			

Typically achieved effluent levels for different water treatment systems

Economics

Process	Investment costs	Operating costs	Water volume flow/ consumption
Open circuit treatment plant	€9.4 – 14.4 million	€0.5 – 0.65/t	4,000m^3/h
Semiclosed circuit treatment plant	€13.0 – 14.5 million	€0.6 – 1.15/t	2,500m^3/h
Closed circuit treatment plant • with cooling tower • with heat exchanger	 €25.0 up to 40.0 million €43.2 million	 €1.45/t €1.6 - 1.75/t	m^3/h additional water consumption (cooling tower) and/or cooling water in large quantities for heat exchangers
Notes: Basis is a production of about 3.0Mt/year hot-rolled products. Investment costs exclude costs for building ground and shops, but include the necessary infrastructure. Operating costs are typical examples only; sludge and dust removal (disposal) is not considered).			

Estimated costs for different water treatment plants

Treatment of scale and oil bearing process water

Scale and oil bearing wastewater from hot rolling (and often from continuous casting) is treated by a sequence of cleaning steps, for example scale pits, settling tanks, cyclones, filtration and so on. These create complex wastewater treatment systems.

The first step is usually a scale pit to remove the coarse scale by sedimentation. This is followed by several secondary or fine cleaning steps to separate and abate oil and the remaining scale.

As there are numerous options for combining the individual cleaning steps, the treatment of scale and oil bearing process waters and the achievable emission levels are described by means of examples of water treatment systems implemented in hot rolling mills.

Main achieved environmental benefits

Reduction of pollutant discharge to water, especially suspended solids, oil and grease.

Applicability

New and existing plants.

Cross-media effects

Oil and sludge arise as waste in wastewater treatment.

Reference plants

Stahlwerke Bremen, Germany; SSAB, Sweden; BSW, Germany.

Example A: SSAB

The major portion of scale and oil is separated into two scale pits near the rolling mill. The water treatment plant has three basins for gravimetric separation of scale and surface separation of oil and grease. The final cleaning is done by 10 sand filters.

The rate of water circulation has gradually been increased over the past years to reduce water discharge to river to below 200m^3/h (former: 3,500m^3/h, recirculation rate approx. >95%). Also, primary measures have been taken to reduce leakage of grease, lubricants and hydraulic oils from machine equipment. Hoses have been changed, better couplings have been installed and routine inspections are carried out.

Achieved discharge values are 0.4mg/l for oil (0.7t/a) and 3.8mg/l for suspended solids (6t/a) (reference year 1994)

Example B: Stahlwerke Bremen

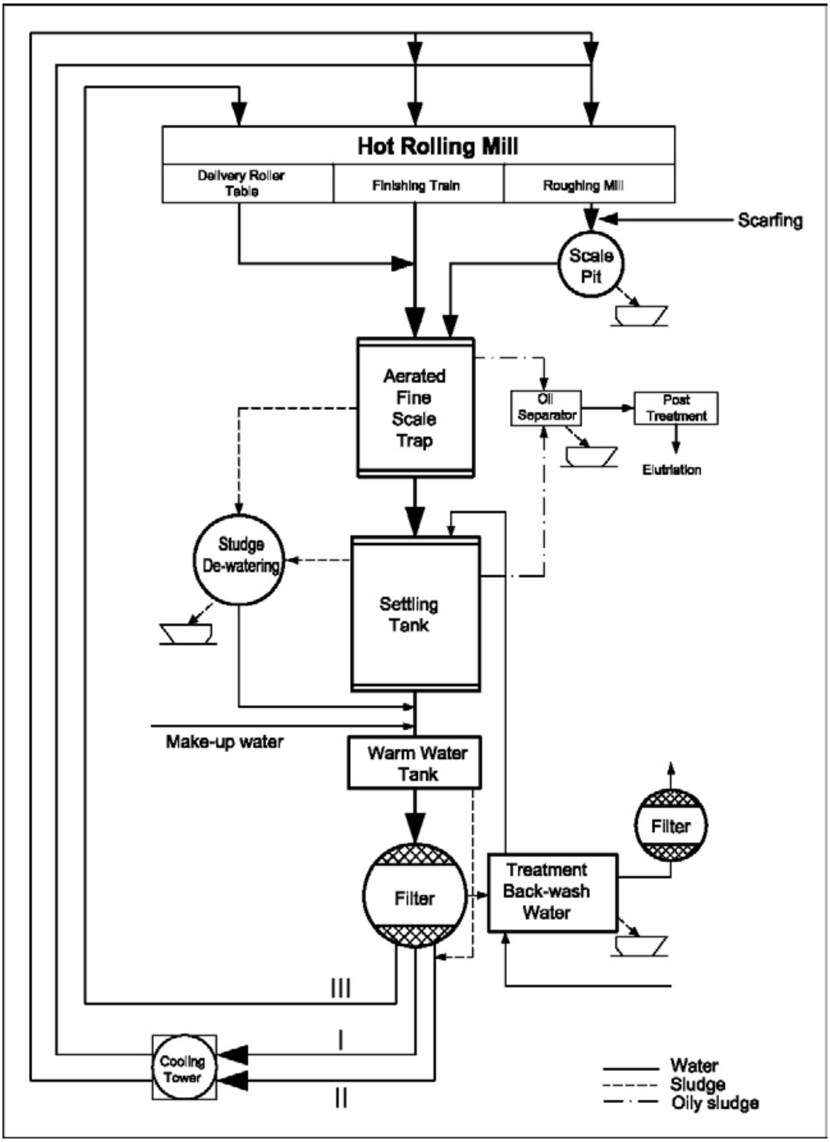
The figure below shows the water circuit and the water treatment system at Stahlwerke Bremen. The system treats an average water flow of 18,000m^3/h; about 3,500m^3/h of which is from the roughing mill and about 14,500m^3/h from the finishing train including water from the delivery roller table, the coiler and the mist extraction system.

Coarse scale is removed from the roughing mill process water in scale pits before it is treated with the stream from the finishing train in aerated fine scale traps followed by settling tanks. Before the water is recirculated and split into different quality streams, it is cleaned in sand filters. These consist of three groups of pressure filters.

Operating at full production capacity, the filtering speed is 21.4m/h. The reduced concentration of suspended solids, iron and hydrocarbons is shown in the table below.

Substance	Scale pits, aerated fine scale trap, settling tank	Sand/Gravelfilter		
	Outlet [mg/l]	Inlet[1] [mg/l]	Outlet [mg/l]	Reduction [%]
Suspended solids	40 – 70	36	3.5 ~ 3.8	90
Iron	10 – 20	7.7	0.85	90
Hydrocarbons	1 – 2	1.7	0.5 ~ 0.6	65
[1]average inlet concentration				

Pollutant concentration in the water circuit



Water circuit and the water treatment system at Stahlwerke Bremen

Stream I: 4,600m^3/h for machine cooling (highest quality, oil <10mg/l)
Stream II: 7,400m^3/h roughing mill and finishing train (medium quality, oil ~15mg/l)
Stream III: 6,000m^3/h delivery roller table (lowest quality, oil <20mg/l)

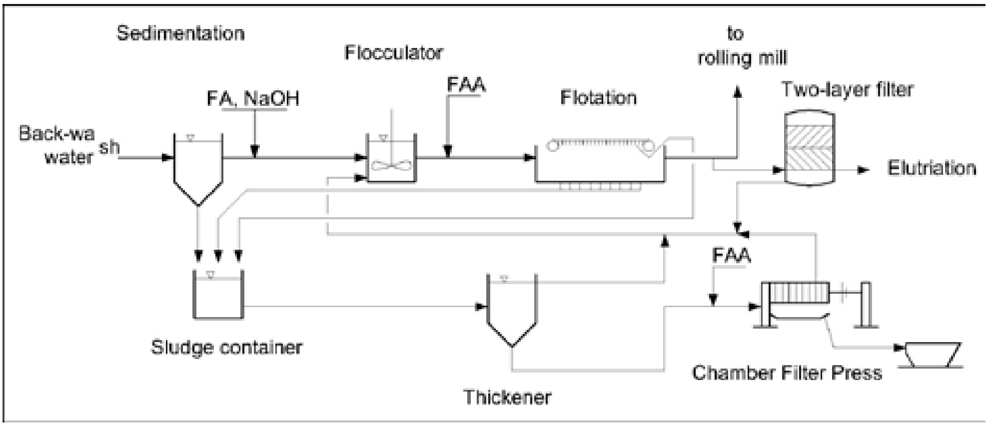
Example of a water recirculation system for a hot rolling mill

To make up for evaporation losses and elutriation water, water from the LD steel plant (or in case of production stop roughly filtered water from a river) is added to the system. The amount of elutriation water, which needs to be withdrawn from the system to avoid salt built-up, is mimimised by reuse for back-washing sand filters and by partial reuse in slag processing.

From filter back-washing about 750m^3/h arise which are treated as shown is in the figure below. About 92% of the solids settle in the sedimentation step; the remaining suspended solids (approx. 50mg/l) and the hydrocarbons (average 1.5mg/l) are treated by flocculation and flotation. The water is then recirculated to the water system.

The partial stream which has to be discarded is treated in two-layer filters. The concentration of suspended solids and hydrocarbons are well below the emission limit values set by authorities (10mg/l SS and 1mg/l HC). Achieved emission levels are shown in the table below.

For maintaining the water circuit, biocides, corrosion inhibitors and dispersing agents are added. Whenever necessary (sometimces once a day) flash chlorination is done.



Treatment of back-washing water: FA = flocculation agent, FAA = filtration aiding agent

Substance	Concentration in mg/l	Type of sampling	Measurements in 1998 Operator/ Competent authority
Fe	0.13	Qualified random sample	12/6
Oil	<0.1	Qualified random sample	12/6
Suspended solids	<3	Qualified random sample	12/6
Cr	<0.01	Qualified random sample	12/6
Ni	0.02	Qualified random sample	12/6
Zn	0.03	Qualified random sample	12/6
Notes: Source of data: Senator für Bau und Umwelt Bremen Plant: Stahlwerke Bremen Mean values of the qualified random samples from 1998 Wastewater volume: 1,620,404m^3			

Concentration of effluents from treatment of back-washing water

Example C: SIDMAR

The water circuit installed at Sidmar consists of three systems: the three bar system for cooling the supporting rolls, the roll table and the motors; the 12 bar system for cooling of the work rolls and for feeding of the discaling pump system and the 150 bar system for descaling at the furnace exits and in the roughing and finishing mill. The total flow is up to 13,000m^3/h.

Oil and scale bearing water from the 150 bar system is cleaned in a first step by scale pits followed by gravity sand filters. The process water from the roughing mill contains mainly large scale, less than 20% of the oil and grease consumption, does not require colling and can be reused in the three bar system without further treatment. Water from the finishing mill contains fine scales and over 80% of the oil and grease consumption. Following the decanters and the sand filters this water needs to be cooled before it is reused in the three bar system. The reused channel water contains less than 5mg/l suspended solids and less than 0.2mg/l hydrocarbons.

Due to evaporation losses and high contents of Na, Cl, etc., about 500m^3/h of refreshing water is needed, which is taken from the cold rolling mill. The elutriated water exits to the steel mill.

The reutilisation rate of the described system is over 95%.

Efficiency of the wastewater treatment and thus the pollutant concentration discharged depends on the combination of individual cleaning operations, among other things. The table below lists more example water treatment sequences and achieved emission levels.

Results of wastewater treatment		
Before treatment	**Treatment**	**After treatment [mg/l]**
Oil/Grease: 10 – 200mg/l 0.7 – 2.73kg/t Suspended solids (SS): 120 – 2,000mg/l 0.13 – 4.57kg/t	Example E Sedimentation + flocculation, flotation + sand filter	Oil: 50 SS: 50
	Example F Sedimentation + flocculation + cooling + sand filter	SS: <10 Oil: <5 Fe: 12 Ni, Cr, Cu, Zn, Pb, Cd: <0.1
	Example G Sedimentation + flocculation + cooling + magnetic filtration[1]	Reduction: SS: 90% (down to 3 – 9 mg/l) Oil: 50 – 90%
	Example B' Sedimentation + aerated sinter removal + flotation + sand filter, blow down: biological polishing	Reduction: SS (>63m): >99% 31 (SS <63m): 20 – 80%
	Example H Cyclones, settling basin, sand filter, cooling towers	Oil: 50 (= 20g/t) SS: 50 (= 20g/t) COD: 100
Notes: Source of data EC Haskoning [1]Concentration before treatment: 30 – 100mg suspended solids/l		

Pollutant reduction for several wastewater treatments

Cooling water treatment

To operate closed cooling water cycles the cooling water has to be re-cooled and treated. Cooling is carried out either by evaporation in cooling towers or by heat exchangers. In pressure-cooled counterflow cooling towers, the water to be cooled is sprayed on grids in the cooling tower cells and flows over blocks into the cooling tower tray. Fans arranged laterally or on top draw off ambient air which passes the water in counterflow. Thus, cooling is achieved by evaporation of water. The cooling efficiency is controlled by means of the air volume. Desalting is controlled via a measurement of the electrical conductivity. If required, the necessary amount of dispersants, sodium hypochlorite and biocide (prevention of growth of bacteria and fungi) and acid or alkali (pH-value) is added.

In plate heat exchangers plates with flow-through channels are screwed to a package. From each plate, alternatively hot wastewater and cold cooling water is pumped through these channels. The heat is transferred via the plate wall.

In hybrid cooling towers, a plate heat exchanger is installed in the upper part of the tower. In the lower part, the water is cooled by evaporation. Due to the heat exchanger, the air with 100% moisture is heated and condenses as fog some time later and with less intensity.

Main environmental benefits achieved

Reduced water consumption, as water can be re-used in the process.

Cross-media effects

- addition of dispersants and of biocides
- increased energy consumption as a result of recirculation pumping requirements.

In the planning and installation of circuit-type water treatment plants with cooling towers the geographical situation of the respective mill has to be taken into consideration. Due to evaporation in the recooling process the climatic conditions can be affected by the constant formation of fog and by the so-called industrial snow, especially in central Europe.

Conclusions

For storing and handling of raw materials and auxiliaries the following techniques are considered to be BAT:

- Collection of spillages and leakages by suitable measures such as safety pits and drainage.
- Separation of oil from the contaminated drainage water and reuse of recovered oil.
- Treatment of separated water in the water treatment plant.

In general, the best way to reduce the environmental impact from surface rectification and conditioning of input is to avoid the need for rectification. The improvement of surface quality of cast products to reduce the need for surface rectification is therefore considered BAT.

Aditionally, for all surface rectification processes, the treatment and reuse of water from all surface rectification processes (separation of solids).

Furthermore, the following measures to minimise energy requirements are considered to be BAT:

In reducing water and energy consumption, material tracking is considered BAT for descaling.

During rolling in the finishing train fugitive emissions of dust occur. The water-related technique that has been identified as BAT for the reduction of these emissions is water sprays, followed by wastewater treatment in which the solids (iron oxides) are separated and collected for reuse of iron content.

The water related best available operational and maintenance techniques for roll shops are:

- use of water-based degreasing as far as technically acceptable for the degree of cleanliness required
- treatment of cooling liquids and cutting emulsions for oil/water separation. Proper disposal of oily residues, e.g. by incineration
- treatment of wastewater effluents from cooling and degreasing as well as from emulsion separation in the hot rolling mill water treatment plant.

For cooling (machines etc.) separate cooling water systems operating in closed loops are considered BAT.

Hot rolling leads to a large amount of scale- and oil-containing process water. The minimisation of consumption and discharge by operating closed loops with recirculating rates of >95% is considered BAT.

Treatment of this process water and pollution reduction in the effluent from these systems as described by examples in this report or by other combinations of the individual treatment units are considered BAT. The following release levels from the wastewater treatment are associated with BAT:

SS:	<20mg/l	
Oil:	<5mg/l	(oil based on random measurements)
Fe:	<10mg/l	
Cr_{tot}:	<0.2mg/l	(for stainless steel <0.5mg/l)
Ni:	<0.2mg/l	(for stainless steel <0.5mg/l)
Zn:	<2mg/l	

As the volume and contamination of wastewater from tube mills are quite similar to other hot rolling operations, it was noted that the same techniques and the same associated BAT levels apply for tube mills.

Recirculation to the metallurgical process of mill scale collected in water treatment is BAT.

Depending on oil content, additional treatment may be required. All oily waste/sludge collected should be de-watered to allow for thermal utilisation or safe disposal.

Throughout the plant the following techniques for prevention of hydrocarbon contamination of water have been identified and are considered to be BAT:

- Preventive periodic checks and preventive maintenance of seals, gaskets, pumps and pipelines.
- Use of bearings and bearing seals of modern design for work and back-up rolls as well as the installation of leakage indicators in the lubricant lines (e.g. at hydrostatic bearings). This reduces the oil consumption by 50 - 70%.
- Collection and treatment of contaminated drainage water at the various consumers (hydraulic aggregates), separation and use of oil fraction, e.g. thermally used by blast furnace injection. Further processing of the separated water either in the water treatment plant or in dressing plants with ultra filtration or vacuum evaporator.

BATs relating to cold-rolling mills

Reduction of wastewater volume contaminant loading

General techniques for the reduction of wastewater volume and contaminant loading include:

- Reduction of iron oxide formation during hot rolling and steel handling (for example, by high pressure descaling, fast cooling, short storage time, corrosion free storage and transport). The acid consumption during pickling is proportional to the amount of iron oxide removed from the steel surface. Although the potential for a reduction in oxide formation is limited, control of the cooling rate can modify the structure of the scale. This can influence the pickling speed and thus reduce energy consumption for the process. Fast cooling of the hot-rolled strip may be limited, however, for quality reasons.
- Partial or full replacement of wet pickling processes by wastewater free mechanical treatment (mechanical descaling). For stainless steel mechanical descaling can only be applied at one part of the process and only partial replacement is viable (Com2 CR). However, it should be recognised that there is an energy penalty associated with the use of mechanical descaling equipment.
- Reduction of acid use and regeneration costs by adding adequate chemicals (inhibitors) for pickling of low alloy and alloy steel (not applicable to stainless steel). However, inhibitors can have a detrimental effect on surface quality (due to the formation of rust).
- Reduction of acid concentration by using high pickling temperatures. Although a balance has to be reached between acid concentration and pickling temperature. The optimum is a function of acid losses, pickling efficiency and energy consumption. Increasing the pickling temperature leads to a rise in NOx generation for stainless steel pickling and therefore avoiding excessive NOx formation needs to be considered in the balance.
- Reduction of acid concentration by using electrical processes.
- Minimisation of wastewater volume by use of cascading flow.
- Minimisation of wastewater volume by using improved pickling and rinsing equipment (mechanical pre-treatment, closed tanks to reduce gas scrubber effluents, spray type treatment instead of dip treatment, squeegee rolls for removal of adhering bath liquor to reduce carry-over of pickle liquor and rinsing water, etc.).

- Internal recycling and mechanical filtering of pickle liquor and rinsing water for lifetime extension.
- Regeneration of pickling acid. Regeneration of waste acids reduces the volume of waste requiring neutralisation. However, the concentration and the volume of waste acid has to reach a certain level to be suitable for regeneration processes.
- Side-stream ion exchange or electrodialysis for bath regeneration.
- Careful selection of raw materials to minimise contamination of waste streams.
- Reduction of the formation of oxide dust (during de-coiling, levelling or in the entry accumulator) by the use of adequate suction heads.
- Indirect heating of acid. The most common way to heat the acid is the use of heat exchangers. Direct heating by steam injection dilutes the waste acid, which therefore cannot be regenerated.

Reduction of dust emission at the decoilers

Iron oxide dust is formed by stretching the strip during the decoiling operation. The formation of dust can be prevented by the use of water curtains. This wet method requires a separator system to remove the iron oxide from the spraying water. This can either be a stand alone system or it is integrated in the global water treatment system of the plant.

In some cases the water spray method leads to an undesired build-up of iron oxide particles on the rolls in the pickling line and hence to roll marks on the strip. In these cases an exhaust system, usually equipped with fabric filters, is used as an alternative to prevent the dispersion of the dust.

Main achieved environmental benefits

- prevention of fugitive dust emissions
- reduction of air emissions.

Applicability

New and existing plants.

Cross-media effects

- consumption of energy
- generation of wastewater or waste (filter dust).

Operational data and economics

Investment costs were reported to be €50,000 for water sprays and €280,000 for an exhaust system with a fabric filter (for a 3Mt/a plant).

Optimised rinsing procedure/Cascade rinsing

For a description, see 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.8.

An optimised rinsing operation aims at reducing the wastewater generated and at minimising contamination of the rinsing water. A common method to reduce the volume of wastewater and sludge from wastewater treatment is to install a (counter-current) cascading flow system in combination with squeegee rolls in the rinsing plant.

Furthermore, spent rinsing water can be reused in the plant, for example for make-up water in pickling baths. Squeeze rolls and wiper rolls are installed behind the pickling baths, as well as before and behind the rinsing baths. Adhering bath liquor from the strip surface is removed to reduce carry-over of pickle liquor from the pickling bath and of concentrated rinsing water from one cascading flow step to the next.

A typical cascade rinse system uses some three to six compartments with wringer rolls to reduce carry-over between compartments. Fresh or condensate water to be added to the last compartment is allowed to cascade counter-currently over a weir to the preceding compartment. The excess, i.e. dragout, overflows from the first compartment to a storage tank from where it is usually passed to the regeneration plant. Portions from the intermediate tanks are taken for acid vapour absorption in the absorption columns of the regeneration plant or for fresh acid dilution in the pickling tanks.

Main achieved environmental benefits

- reduced water consumption
- reduction of wastewater volume and sludge from wastewater treatment
- reduction of acid consumption.

Applicability

New and existing plants.

Reference plants

Jenn An, Taiwan

Cleaning and reuse of acid pickle liquor

Side-stream mechanical filtering, acid recovery and internal recycling can be used for cleaning and extending the lifetime of the pickling liquor. The liquor is filtered, e.g. in deep bed media filters, to remove particulates. Cooling of the acid by means of heat exchangers might be necessary prior to the adsorption unit in which a physio-chemical adsorbent (like a resin) removes free acid from the waste stream. Once the unit is saturated the free acid is desorbed by a freshwater stream and recycled to the pickling process.

Main achieved environmental benefits

Reduced acid consumption (wastewater volume and sludge).

Applicability

New and existing plants.

Cross-media effects

Increased energy consumption.

Reference plant

Allegheny Ludlum, USA

Hydrochloric acid regeneration by spray roasting

See 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.5.10.1.2 for regeneration process description and chapter D.5.3 for emission abatement.

Main achieved environmental benefits

- reduced consumption of fresh acid (from 12 - 17.5kg/t to 0.7 - 0.9kg/t; HCl conc. 33%)
- reduced wastewater volume and sludge.

Applicability

New plants and existing plants depending on size.

Cross-media effects

- consumption of energy and water
- generation of air emissions (combustion product and acid), which have to be reduced by e.g. wet scrubbers
- generation of wastewater, which has to be treated
- specific emission of suspended solids of 2.86g/t product (in treated wastewater)
- reduction of new acid to be produced (supplier)
- generates a sellable solid by-product: iron oxide, which can be reused in the ferrite industry or in colour- and glass production.

Company	Year of contract	Capacity [l/h]	Remarks
Hoesch Stahl AG, Dortmund, Germany	1989	9,000	
Ornatube Enterprise, Kaohsiung, Taiwan, China	1989	900	
Shanghai Cold Strip, China	1989	2,900	
China Steel, Kaohsiung, Taiwan, China	1989	1,900	
Sidmar S.A, Ghent, Belgium	1990	11,000	
Anshan Iron & Steel, China	1991	2 x 6,000	high-purity oxide
Benxi Iron & Steel, China	1992	5,000	
Karaganda Met. Komb. Kazakhstan	1992	2 x 10,000	
MMK, Magnitogorsk, Russia	1993	11,000	
Baoshan Iron & Steel, China	1994	2 x 2,900	high-purity oxide
Hanbo Steel, Korea	1994	11,000	

Reference plants

Operational data

The tables below present data on consumption and emissions associated with HCl spray roasting.

Input/Consumption level		
Spent acid	0.7 – 0.9	kg/t
Cooling water (in)	0.07 – 0.09	m^3/t
Industrial + demineralised water	0.09 – 0.15	m3/t
Energy:		
- Electrical energy	4 – 15	MJ/t
- Caloric energy (natural gas)	102 – 119	MJ/t
Output/Emission level		
	Specific emission	
Solid by-product: Fe_2O_3	5.1 – 5.4 (5.6 Sidmar)	kg/t
Recycled acid (20%)	23 – 40	kg/t
Cooling water (out)	0.07 – 0.09	m^3/t
Waste gas	24 – 38	m^3/t
Wastewater (discharge)	0.04 – 0.07	m^3/t

Consumption and emission levels for HCl spray roasting

	Concentration [mg/Nm³]	Specific emission [kg/t product]	Reduction rate[1] [%]	Method of analysis
Dust	20 – 50	n.a.	n.a.	EPA
SO_2	50 – 100	n.a.	n.a.	SO_4 detection by ion chromatography (NBN T95-202)
NO_2 [2]	300 – 370	0.014	>90	NO3 detection by ion chromatography (NBN T95-301), Luminiscence
CO	150	0.006	>90	Umwelt-BA EM-K1
CO_2	180,000	6855	>90	Infrared
HCl	8 – 30	3.05 E-4	>98	Ion chromotography (ASTM D 4327-84), Potentiometric titration
(NEN 6476)				
[1]Reduction rate based on mass flow of constituent before/after abatement measure [2] (3% O_2)				

Emissions to air from HCl spray roasting

Plant supplier claim pollutant concentrations of less than 2mg/m³ of HCl and free Cl2.

For a counter-current packed water scrubber with final alkaline scrubbing HCl emission levels of <15mg/m³ with investment cost of 1175 kECU and operating costs of €6,000/a (electricity 300kWh, V=10,000m³/h) were reported.

Hydrochloric acid regeneration by fluidised bed

For the description see 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001. Chapter D.5.10.1.1 covers regeneration process description and Chapter D.5.3 covers emission abatement.

Main achieved environmental benefits

- reduced consumption of fresh acid
- reduced wastewater volume and sludge.

Applicability

New plants and existing plants depending on size.

Economics

The economics of a modern pickling plant, including the fluidised bed process, involve the following factors:

- raw acid consumption
- utilisation of rinse and scrubber water
- production of clear, iron-free hydrochloric acid
- production of iron oxidem which can be used in different industries.

Generally, the capital costs of a pickling plant, including fluidised bed process, are favourable compared with the operation costs and resulting benefits. Overall economics will vary from one installation to another, due to local differences in acid cost, waste pickle liquor regeneration cost and the cost involved in modernising existing facilities or constructing new facilities.

Effluent-free HCl strip pickling plant

In determining the wastewater from pickling operation, spent pickle liquor, rinse wastewater and scrubber water have to be taken into account. Using the fluidised bed process, the pickle liquor recycled between the pickling tanks and regeneration unit results in a nearly zero consumption of raw acid apart from some small amount of evaporation loss.

Since the fluidised bed process operates at approximately 850°C, additional rinse and scrubber water from the pickle line can be used in the regeneration plant. In accordance with the energy balance of the venturi scrubber, a certain amount of water is necessary for cooling the reactor off-gas by evaporation.

The quantity of rinse and scrubber water, which can be used in the fluidised bed process, depends on the iron content of pickle liquor. A portion of the rinse water is used for absorption, with the remainder directly added to the venturi scrubber.

An economical effluent-free pickling line operation can be achieved considering spent pickling liquor as well as rinse water quantities and concentrations. This process is capable of operating a completely closed, effluent-free pickling, plant and has already been installed in several modern facilities. These facilities are operating with hydrochloric acid consumption of less than 0.2kg acid/tonne of pickled material.

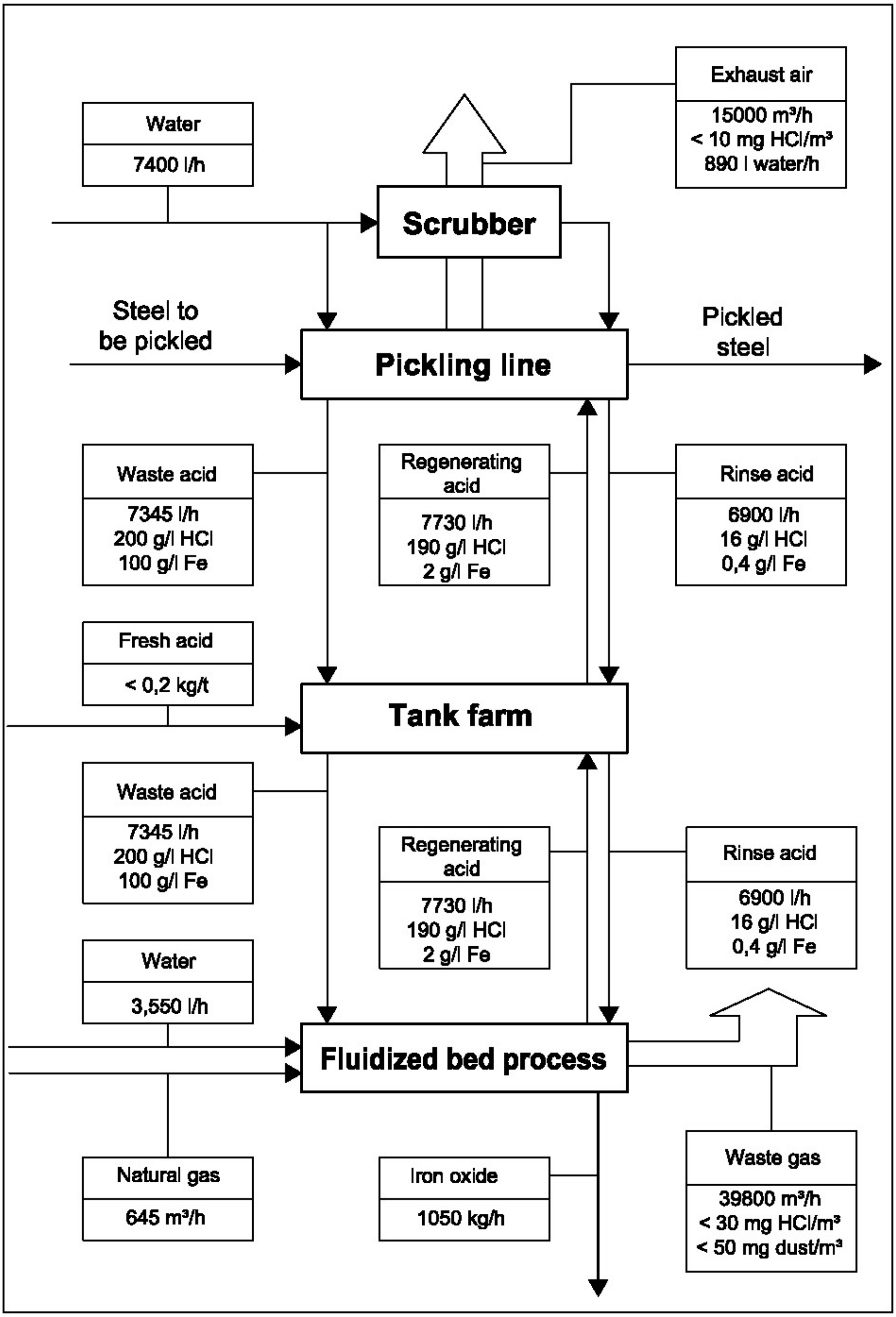
One example of effluent-free strip pickling line in operation is illustrated in the figure below.

Main achieved environmental benefits

No water discharge/pollution.

Applicability

New plants and existing plants, depending on their size.



Example of effluent-free HCl pickling and acid regeneration

Sulphuric acid recovery by crystallisation

For a description, see 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.5.9.1 and D.5.3 for reduction of air emissions (scrubbing).

Main achieved environmental benefits

- reduced consumption of fresh acid
- reduced wastewater volume and sludge.

Applicability

New plants and existing plants, depending on their size.

Cross-media effects

- increased energy consumption
- emissions to air from recovery.

Operational data

The table below presents data on consumption and emissions associated with H_2SO_4 vacuum crystallisation.

Input/Consumption level		
Spent acid	7 – 10	kg/t
Cooling water (in)	2 – 3.5	m^3/t
Industrial + demineralised water	0.2 – 0.4	m^3/t
Energy:		
- Electrical energy	1 – 20	MJ/t
- Caloric energy	100 – 200	MJ/t
Output/Emission level		
	Specific emission	
Solid by-product: Fe-sulphate	26 – 30	kg/t
Recycled acid (20%)	0 – 10	kg/t
Cooling water (out)	2 – 3.5	m^3/t
Waste gas	70 – 90	m^3/t
Wastewater (discharge)	0.2 – 0.4	m^3/t

Consumption and emission levels for H_2SO_4 vacuum crystallisation

Mixed acid regeneration by spray roasting

For a description, see the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.5.10.1.2 and D.5.3.

Main achieved environmental benefits

- reduction in fresh acid consumption (from 2.5 -7. kg/t HF and 3 - 10 kg/t HNO_3 down to 0.8 - 1.2 kg/t HF), reduction of new acid to be produced (supplier).
- reduction of neutralisation sludge.

Applicability

New and existing plants.

Cross –media effects

- consumption of energy and chemicals
- generation of air emissions, which have to be reduced/controlled
- generation of wastewater, which has to be treated
- generation of usable by-product mixed oxide.

Reference plants

Company	**Capacity [l/h]**	**Starting year**
Acerinox, Spain	3,000	1992
Yieh United, Taiwan, China	4,500	1994
POSCO, Korea	4,500	1994
Columbus, South Africa	4,500	1995

Operational data

The table below presents data on use and emissions of mixed acid regeneration by spray roasting.

Input/Consumption level	
Spent acid	25 – 100 kg/t
Cooling water (in)	1.5 – 9 m^3/t
Urea (for Denox)	0.4 – 1 kg/t
Caustic soda	
Energy:	
- Electrical energy	5 – 20 MJ/t
- Caloric energy (natural gas)	60 – 230 MJ/t
Output/Emission level	
Solid by-product: mixed oxide	1.7 – 5 kg/t
Recycled acid (HF 6%, HNO_3 10%)	26 – 108 kg/t
Cooling water (out)	1.5 – 9 m^3/t
Waste gas:	25 – 100 m^3/t
NOx	<100 ppm (= 200 mg/m^3 calc. NO_2)
HF	< 2 mg/Nm^3
Dust	< 10 mg/Nm^3
Wastewater	0.003 – 0.01 m^3/t

Consumption and emissions of mixed acid regeneration by spray roasting

Economics

Savings due to reduced acid consumption and sellable by-product.

Mixed acid (HNO_3 and HF) recovery by ion exchange

For a description, see the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.5.9.3.

Main achieved environmental benefits

Reduction of waste and fresh acid consumption.

Applicability

New and existing plants.

Operational data

Input/Consumption level		
Spent mixed acid	0.05 – 0.2	m^3/t
Water	0.05 – 0.2	m^3/t
Energy:		
- Electrical energy	2 – 5	MJ/t
Output/Emission level		
	Specific emission	
Recovered mixed acid	0.05 – 0.2	m^3/t
Free HF recovery rate	75 – 85%	
Free HNO_3 recovery rate	80 – 85%	
Metals removal rate	50 – 55%	
Metal containing weak acid solution	0.05 – 0.2	m^3/t

Consumption and emission levels for mixed acid recovery by ion exchange

Mixed acid recovery by evaporation

For a description, see the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapters D.5.10.4 and D.5.10.5.

Main achieved environmental benefits

- reduction of fresh acid consumption by recycling both free and bounded HNO_3 and HF
- no nitrates in wastewaters
- no dust emissions.

Applicability

New and existing plants.

Cross-Media effects

- consumption of energy and H_2SO_4
- generation of metal sulfates, which can neutralised to metal hydroxides.

Operational data

Input/Consumption level	
Spent acid	15 – 30 litres/t
H_2SO_4 (95%)	4.0 – 6.0 kg/t
Cooling water	3.8 – 5.8 kg/t
Energy:	
- Electricity	2.3 – 3.5 MJ/t
- Steam	16 – 24 kg/t
- Propan	3.2 – 4.8 MJ/t
Output/Emission level	
Cooling water	3.8 – 5.8 kg/t
Recycled acid:	14 – 20 litres/t
130 g/l HNO_3	
55 g/l HF	
Metal sulphate:	5.0 – 7.6 kg/t
Fe	0.6 – 0.8 kg/t
Cr	0.09 – 0.13 kg/t
Ni	0.08 – 0.12 kg/t
SO_4	1.9 – 2.9 kg/t
H_2SO_4	1.7 – 2.5 kg/t
Waste gas:	
Dust	None
HF	<2 mg/l
NO_2	<100 mg/l
The data above is based on measurements during plant operation.	

Consumption and emission levels for mixed acid recovery by evaporation

Reduction of emissions from pickling/closed HCl and H_2SO_4 pickling tanks with exhaust gas scrubbing

For a description, see the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.5.2 and D.5.3.

The various working steps of the pickling process are carried out in totally enclosed equipment or in equipment fitted with hoods. The acid fumes generated are extracted and passed through gas scrubbers (absorption towers) for cleaning. Recycling water, for example from rinsing, is used as absorbent. Partial flow of the scrubbing water has to be discharged via the neutralisation plant.

Main achieved environmental benefits

Reduction of emissions to air, especially of fugitive acid fumes.

Applicability

New plants and existing plants.

Cross-media effects

- increased energy consumption
- generation of acidic wastewater, which can be used in the process, e.g. as rinse water for HCl regeneration, or require neutralisation followed by water treatment (associated with consumption of chemicals and generation of water treatment sludges).

Reference plants

Jenn An, Taiwan, China

Reduction of emissions from pickling/closed mixed acid pickling tanks with exhaust gas scrubbing

For a description, see the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.5.2, D.5.3 (fabric filter) and D.5.8.3. scrubbing with H2O2, NaOH and urea.

Main achieved environmental benefits

Reduction of emissions to air, especially of fugitive acid fumes (HF and NOx).

Applicability

New plants and existing plants.

Cross-media effects

- scrubbing with H_2O_2 results in a nitric acid by-product with a concentration that allows recycling to the pickling process
- reduction of nitric acid consumption
- reduced wastewater volume and wastewater treatment sludge

- in case of H_2O_2 or urea injection in the pickling bath, scrubbing water can be reused as make up water in the pickling tanks
- scrubbing with sodium hydroxate results in a sodium nitrate waste which is disposed of.

Reference plants

Thyssen Stahl, Krefeld, Germany; Allegheny Ludlum, USA

Magnetic pumps (low alloy and alloy steel)

Mechanical pumps need a constant gland water flow on the mechanical seals. Substitution of mechanical by magnetic pumps reduces the water needs.

Main achieved environmental benefits

Reduction of water consumption.

Applicability

New and existing plants.

Treatment of acidic wastewater

Acidic wastewater from rinsing and from fume absorbers of the pickling tank exhaust system – if it cannot be used in the pickling tanks – and the wastewater from flushing (plant cleaning) require treatment prior to discharge. The wastewater is neutralised (for example with alkaline wastewaters from other plant operations), dissolved metal ions are transformed into hydroxides or sparingly soluble salts and subsequently eliminated by sedimentation, in many cases by adding flocculants. The precipitated metal sludge is de-watered in filter presses and disposed of.

Main achieved environmental benefits

Reduction of volume and contaminant load to water.

Applicability

New and existing plants.

Cross-media effects

- generation of a large quantity of sludge
- the sludge, mainly consisting of iron hydroxide and water, can be recycled for iron production as long as it is not contaminated by unacceptable metals (e.g. zinc) or by other constituents. Care should be taken to avoid mixing of wastewater streams or sludges which can make recycling difficult.

- neutralisation can also create large amounts of neutral salts (e.g. $NaCl$, $CaCl_2$, Na_2SO_4, $CaSO_4$), most of which are very soluble in water and are discharged with the treated water. Removal is only possible by very special, and in most cases uneconomical, treatment (reverse osmosis, electrodialysis or evaporation followed by ion exchange and concentrate evaporation with salt drying). Even if these salts are removed, their mixed composition limits re-use and disposal to landfill may be restricted by their solubility.

Operational data

	Concentration [mg/l]	Specific emission [g/t product]	Reduction rate[1] [%]	Method of analysis
Suspended solids	50	2.86	>90	DIN 38409-H2
Fe total	2	0.114	>90	DIN 38406
Zn total	0.06 – 1			"
Ni total	0.1 – 0.5			"
Cr total	0.02 – 0.5			"
Cr VI	0.01 – 0.1			"
Temperature	<30°C			Thermometer
pH	6.5 – 9.5			DIN38404-C5
Data based on weekly, volume proportional 24-hour sampling [1]Reduction rate based on mass flow of constituent before/after abatement measure				

Pollutant concentration in water discharge of HCl pickling and regeneration plants, 1

Substance	Concentration [mg/l[1]]	Type of sampling	Measurements in 1998 Operator/Comp. authority
Fe	0.41	Qualified random sample	12/6
Oil	<0.28	Qualified random sample	12/6
Suspended solids	<10	Qualified random sample	12/6
Cr	<0.01	Qualified random sample	12/6
Ni	0.03	Qualified random sample	12/6
Zn	0.02	Qualified random sample	12/6
Plant: Stahlwerke Bremen [1]Mean values of the qualified random samples from 1998. Wastewater volume: 264,528m^3			

Pollutant concentration in water discharge of HCl pickling and regeneration plants, 2

	Concentration [mg/l]	Specific emission [g/t product]	Reduction rate[1] [%]	Method of analysis
Suspended solids	40 – 50	16 – 20	>90	DIN 38409-H2
Fe total	1.4 – 2	0.3 – 0.5	>95	DIN 38406
Zn total	0.15 – 1			"
Ni total	0.1 – 0.5			"
Cr total	0.5			"
Cr VI	0.01 – 0.1			"
Temperature	< 30°C			Thermometer
pH	6.5 – 9.5			DIN38404-C5
Data based on weekly, volume proportional 24-hour sampling [1]Reduction rate based on mass flow of constituent before/after abatement measure				

Pollutant concentration in water discharge of H_2SO_4 pickling and regeneration plants

Prevention of contamination

A regular check of the seals and piping helps to prevent leakage and thus contamination of the rolling emulsion with hydraulic oil or Morgoil oil.

Main achieved environmental benefits

- reduced emulsion consumption
- reduced wastewater treatment and discharge.

Applicability

New plants and existing plants.

Cleaning and reuse of emulsion

See also the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.3.1.

Rolling emulsions from the mill stands are sprayed onto the rolls for cooling, lubrication and cleaning. Contamination of the rolling emulsion occurs due to the pick up of particulate matter, steel slivers, scale and dust. Nowadays, emulsions systems are operated as circulation systems, in which cleaning devices are integrated to maintain emulsion quality and thus minimize damage to the surface finish of the strip.

Settling tanks, separators, mesh filters, magnetic filters and so on are used to remove impurities from the emulsion. Only a partial flow needs to be discarded from the circuit and is treated in emulsion splitting plants and finally discharged.

Main achieved environmental benefits

- reduced consumption of new cold rolling emulsion
- reduced wastewater volume.

Applicability

New and existing plants.

Treatment of spent emulsion

See also the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.3.2.

The partial flow of the emulsion circuit cleaning system that is discarded, is de-oiled in an emulsion splitting plant and/or split into oil sludge and water, and the purified water is then discharged. The separated, oil-containing sludge may be e.g. used in the blast furnaces in an integrated steel work.

The figure below shows an example of an emulsion splitting system using electrolytic splitting.

Main achieved environmental benefits

Reduced emissions to water.

Applicability

New plants and existing plants.

THERMAL TREATMENT:

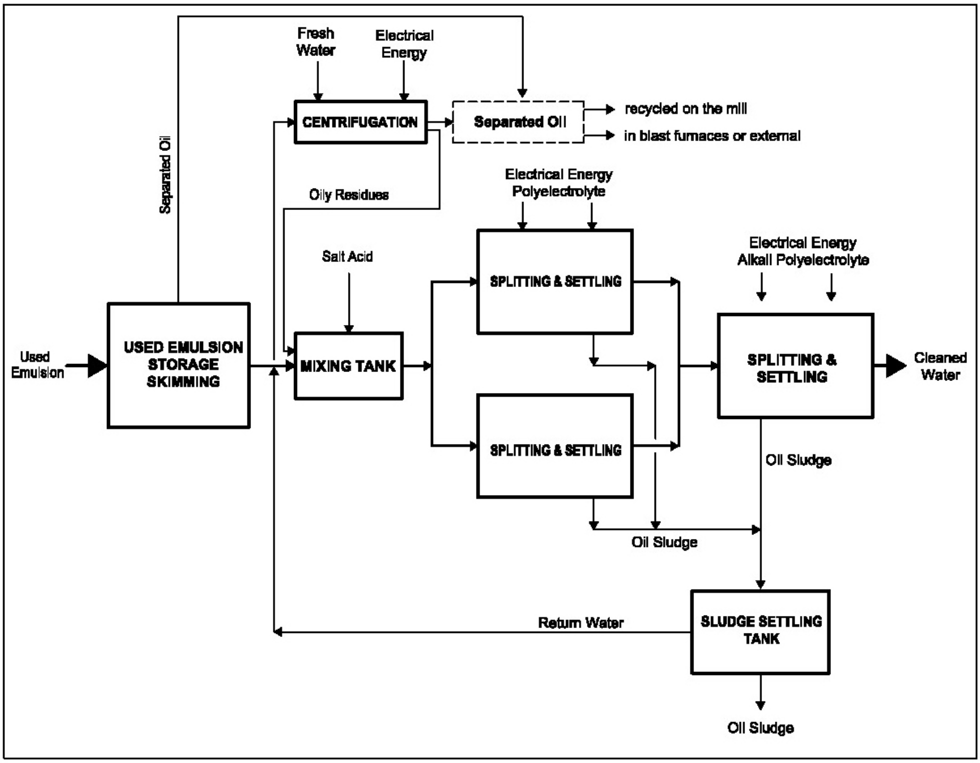
Cross-media effects

- high energy consumption
- waste gas treatment required
- little COD in effluent.

Chemical treatment:

Cross-media effects

- generation of additional oil-containing neutralisation sludges
- consumption of chemicals
- COD in effluent.



Spent emulsion splitting system

Input/Consumption level				
	Tandem mill		Reversing mill	
Spent emulsion	5 –13	kg/t	0.06	m^3/t
Industrial water	0.5 – 1	kg/t		kg/t
Salt	0.025 – 0.05	kg/t	0.125 (NaCl)	kg/t
Polyelectrolyte	0.003 – 0.005	kg/t	0.012	kg/t
Al-Anodes	0.003 – 0.006	kg/t	0.012	kg/t
Electrical energy	5 – 10	MJ/t	3 - 3.5	MJ/t
Output/Emission level				
Purified wastewater	5 – 13	kg/t	0.06	m^3/t
Water (→ coke plant)				
Oily sludge (disposal)	0.1 – 0.3	kg/t	1.9	kg/t
Oily sludge (internal recycling)	2.5 – 3.5	kg/t		
Oil (+/- 20 % water, → blast furnace)	1.3 – 2	kg/t		
	Concentration [mg/l]	**Specific Emission [kg/t product]**	**Reduction rate[1] [%]**	**Method of analysis**
Settleable solids	7 – 10	5.8 – 8 E -5	>90	DIN 38409-H9
Σ Hydrocarbons	6 – 18	5.2 – 18 E -5	>90	DIN 38409-H18
Chlorides	800 – 1,400	6.7 – 10 E -3		DIN 38405-D1
Sulfide	0.004 – 0.4	3.3 – 330 E -8		DIN 38405-D26
NO_2^-	8 – 10	8 – 9 E -5		DIN 38405-D19
Pb Total	0.03 – 0.3	2.65 – 27 E -7	>90	DIN 38406
As Total	0.075 – 0.1	6.2 – 7.5 E -7	>90	DIN 38406
Zn total	0.08 – 1.6	6.6 – 132 E -7	>90	DIN 38406
Ni total	0.4 – 0.5	3.3 – 4 E -6	>90	DIN 38406
Cr Total	0.008 – 0.4	6.6 – 2,500 E -8	>90	DIN 38406
Cu total	0.06 – 0.4	5 – 33 E -7	>90	DIN 38406
AOX	0.1 – 0.4	8.3 – 32 E -7		DIN 38409-H14
BTX	0.02 – 0.08	1.7 – 6.6 E -7		DIN 38407-F9
Temperature	28°C			Thermometer
pH	7.6			DIN 38405-C5
Note: Data based on weekly, volume proportional 24-hour sampling				

Operational data for electrolytic emulsion splitting

Ultrafiltration:

Cross-media effects

- no chemical addition required
- no oily sludge is generated
- nearly 100 % oil removal efficiency, independent of influent oil content.

Reference plants

SIDMAR, Ghent, Belgium

Economics

Saves costs.

Cooling water cycles/Special cooling water systems

The heat generated during cold rolling is usually rejected via plate heat exchangers to cooling water circuits. Water from these circuits may be recirculated to minimise consumption by rejecting the heat via evaporative cooling towers or secondary cooling circuits.

Special cooling water system

The risk of contaminating the cooling water with oils can be minimised.

Reuse of cooling water

Saving natural resources and energy in the cooling water cleaning system.

Operational data – Cooling water system

Input/Consumption Level		
Cooling water (re-circulating)	8,400m³/t	
River water	7,000m³/t	
Soft water[1]	2.5 E -4 m³/t	
NaOH	1.25 E -8 m³/t	
Inhibitor	2.5 E -7 m³/t	
Energy		
- Electrical	0.004GJ/t	
- Caloric[2]	0.282GJ/t	
Output/Emission Level		
	Specific Emission	**Concentration**
Cooling water (re-circulating)	8,400m³/t	
Wastewater (system drain water)	2.5 E -4 m³/t	
Settleable solids (volume)	2 – 5ml/l	
Hydrocarbons (oil, grease)	2 – 5mg/l	0.5 – 1.25mg/t
Chlorides	50mg/l	12.5mg/t
Fe total	2mg/l	0.5mg/t
Temperature	35°C	
pH	6.5 – 9.5	
Electric conductivity	1.1mS/cm	
Notes: Data based on weekly, volume proportional 24-hour sampling [1]only in case of system drainage [2]energy removed from tandem mill by cooling water		

Consumption and emission levels for the cooling water system of a tandem mill

Cleaning and reuse of degreasing solution

See also the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.4.3.

High oil contents make the degreasing solution unusable and cleaning measures are applied to extent the lifespan of the bath. Measures to clean the degreasing bath and to extend the lifetime are:

1. magnetic separators to remove the mixture of iron fines and oil
2. mechanical cleaning
   Usually the emulsions of degreasing agents and oil/grease from the metal surface are unstable and after some time they float on the surface of the bath. They can be removed by skimmers. Suspended particles are removed by sedimentation in gravity separators. Mechanical cleaning can extend the lifetime of degreasing baths 2 – 4 times.
3. adsorption of surfactants and oil (precipitation followed by filtration)
4. ultrafiltration.

Main achieved environmental benefits

- consumption of chemicals for new alkaline baths can be drastically reduced
- reduction of wastewater treatment and discharge.

Applicability

New plants and existing plants.

Cross-media effects

Oil and grease arise as waste in the cleaning of degreasing solutions. This waste may be used for energy recovery or has to be disposed of by incineration.

Operational data

The tables below presents input/output data and effluent data for degreasing solution cycle of a continuous annealing line, which is maintained by cleaning via ultrafiltration.

Input/Consumption level				
Degreasing solution	50 – 60kg/t			
Demineralised water	0.3 – 0.4kg/t			
Degreaser	0.04 – 0.05kg/t			
Tempering fluid concentrate	0.15 – 0.2kg/t			
Electrical energy	4 – 5MJ/t			
Output/Emission level				
Cleaned degreasing solution	40 – 50 kg/t			
Sludge	0.4 – 0.5 kg/t			
	Concentration [mg/l]	**Specific emission [g/t product]**	**Reduction rate[1] [%]**	**Method of analysis**
Suspended solids (filterable)	20 – 40	2.35 – 4.7 E -4	>90	DIN 38409-H2
Σ Hydrocarbons (oil, grease)	5 – 8	5.9 – 9.4 E -5	>90	DIN 38409-H18
Fe total	1 – 2	1.2 – 2.4 E -5	>90	DIN 38406
Temperature	30°C			Thermometer
pH	6.5 – 9.5			
Note: Data based on weekly, volume proportional 24-hour sampling [1]Based on mass flow of constituent				

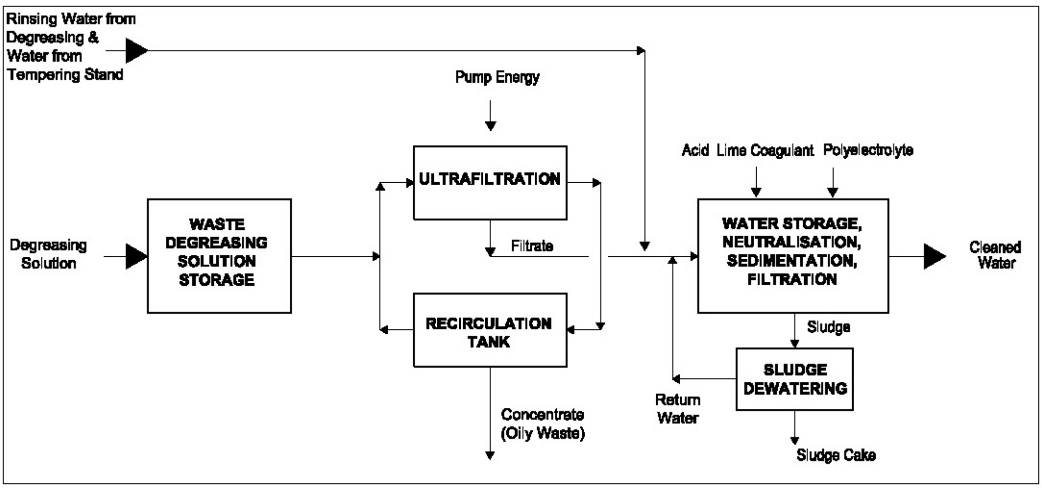
Operational and effluent data for degreasing bath cleaning by ultrafiltration

Treatment of spent degreasing bath and alkaline wastewater

See also the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapters D.4.4 and D.4.5.

Partial flows from the degreasing solution cleaning circuit, rinsing water from the electrolytic degreasing and wastewater from the skin pass mill stand, which cannot be reused in the mills, have to be treated prior to discharge.

Prior to treatment of the wastewater withflocculants, the oil contend has to be removed, for example by ultrafiltration. Then the wastewater is usually neutralised with lime or HCl in a neutralisation plant, passed through filters and finally discharged. The sludge is dewatered in filter presses and discharged for landfill deposit. The oil sludge from the ultrafiltration plants can be used in the blast furnaces.



Spent degreasing solution flow (example of a continuous annealing line)

Main achieved environmental benefits

Reduced emissions, especially oil, to water.

Applicability

New and existing plants.

Cross-media effects

Energy and raw material consumption.

Operational data

The table below presents input/output data and effluent data for alkaline (degreasing) wastewater treatment by ultrafiltration (continuous annealing line).

Input/Consumption level				
Raw wastewater	12 – 15 kg/t			
Citric acid	occasionally kg/t			
Electrical energy	1 – 1.5 MJ/t			
Output/Emission level				
Purified wastewater	12 – 15 kg/t			
Sludge	kg/t			
	Concentration [mg/l]	**Specific emission [g/t product]**	**Reduction rate[1] [%]**	**Method of analysis**
Suspended solids (filterable)	20 – 40	2.35 – 4.7 E -4	>90	DIN 38409-H2
Σ Hydrocarbons (oil, grease)	5 – 8	5.9 – 9.4 E -5	>90	DIN 38409-H18
COD	5,000 – 6,000	5.9 – 7.1 E -5	>50	DIN 38409-H44
Temperature	30°C			Thermometer
pH	6.5 – 9.5			
Note: Data based on weekly, volume proportional 24-h sampling [1]Reduction rate based on mass flow of constituent				

Operational and effluent data for alkaline wastewater treatment

Extraction system for degreasing facilities

Fumes from degreasing baths and the pre-cleaning section of continuous annealing lines are extracted by an exhaust system and passed through gas scrubbers for cleaning. Recycled water is used as an absorbent. Partial flow of the scrubbing water has to be discharged via the water treatment facilities of the degreasing line or, respectively, the continuous annealing plant.

Main achieved environmental benefits

Reduced fugitive emissions of degreasing fumes.

Cleaning of temper mill emulsion

The used temper mill emulsion has to be cleaned before disposal. This emulsion is generally treated together with the tandem mill emulsion and the other oily residues in the emulsion treatment system.

Main achieved environmental benefits

Reduced emissions to water.

Applicability

New and existing plants.

Cross-media effects

Energy and raw material consumption.

Conclusions

At the entry side of pickling lines, decoiling of the hot-rolled strip leads to fugitive dust emissions. For the reduction of these emissions, one water related technique has been identified as BAT: water curtains followed by wastewater treatment in which the solids are separated and collected for reuse of iron content.

For mixed acid pickling, free acid reclamation (e.g. by side-stream ion exchange or dialysis) or acid regeneration (e.g. by spray roasting or evaporation process) are considered BAT.

While free acid reclamation is applicable to virtually all plants, the applicability of regeneration processes may be limited for site-specific reasons. The emissions associated with BAT are:

	Spray roasting	Evaporation process	Free acid reclamation
Dust	<10mg/Nm³	None	None
HF	<2mg/Nm³	<2mg/Nm³	
NO_2	<200mg/Nm³	<100mg/Nm³	
Wastewater	0.003 – 0.01m³/t	not available	0.05 – 0.02m³/t (metal-containing weak acid solution)
Other output	mixed oxide	metal sulphate filter cake	

All three processes are considered BAT. Despite the disadvantage of higher air emissions and energy consumption, spray roasting was selected because of its high acid recovery rate and associated low fresh acid consumption. Furthermore, the wastewater is only a fraction of that produced by reclamation processes. Metals are basically bound in a solid by-product. This mixed iron-chromium- nickel oxide can be reused in metal production.

The evaporation process also provides a very high acid recovery rate and thus low fresh acid consumption, but with much lower energy consumption than spray roasting. The metal sulphate filter cake, however, needs to be disposed of.

For heating of acids the direct injection of steam is not considered BAT as it leads to unnecessary dilution of the acid. BAT is indirect heating by heat exchangers or, if steam for heat exchangers has to be produced first, by submerged combustion.

The following measures have been identified as BAT for the minimisation of acidic wastewater:

- cascade rinsing systems with internal reuse of overflow (e.g. in pickling baths or scrubbing)
- careful tuning and managing of the 'pickling-acid regeneration-rinsing' system. Some sources report a possible wastewater-free operation
- in any case where acidic water blow-down from the system cannot be avoided, wastewater treatment is required (neutralisation, flocculation, etc.). Associated release levels of the wastewater treatment are:

SS:	<20mg/l	
Oil:	<5mg/l	(oil based on random measurements)
Fe:	<10mg/l	
Cr_{tot}:	<0.2mg/l	(for stainless steel < 0.5mg/l)
Ni:	<0.2mg/l	(for stainless steel < 0.5mg/l)
Zn:	<2mg/l	

There was agreement that there are exceptional cases for stainless steel where the levels of Cr_{tot} and Ni cannot be kept below 0.5mg/l.

For installations operating with a degreasing step, the following water related techniques are considered BAT:

- treatment of spent degreasing solution by electrolytic emulsion splitting or ultrafiltration to reduce the oil content. The separated oil fraction should be reused, e.g. thermally; the separated water fraction requires treatment (neutralisation, etc.) prior to discharge.
- extraction system to capture degreaser fume and scrubbing of extracted air.

For cooling (machines, etc.), separate cooling water systems operating in closed loops are considered BAT.

For the roll shops of cold rolling mills the same principles apply as for roll shops in hot rolling mills.

BATs relating to finishing and galvanizing

Galvanizing of sheet (zinc and zinc alloy coating)

Cascade (multiple) use of degreasing solutions

The solution from the electrolytic degreasing section is reused in the spray section, once a certain oil level is reached. The spent degreasing solution of the spray section is sent away to be regenerated. The oil residues out of the regeneration devices are incinerated out of the site, and the rinse waters are treated in the main water treatment plant. Leakages and splashes are collected and treated.

Main achieved environmental benefits

- reduced degreasing solution consumption (freshwater consumption)
- reduction of wastewater and sludge in the water treatment plant.

Applicability

New and existing lines, provided space is available.

Cross-media effects

Increased energy consumption.

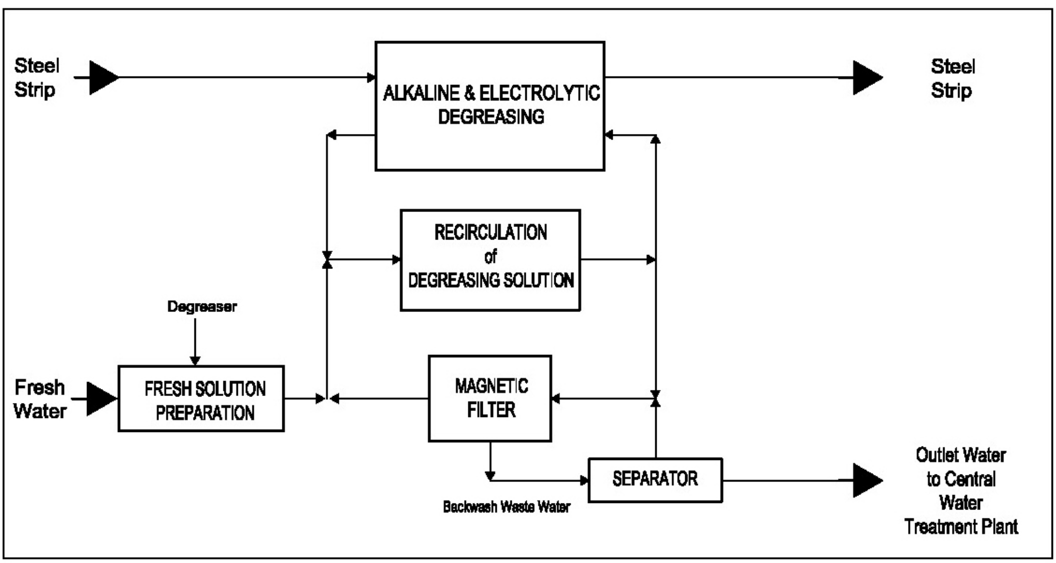
Operational data

15m^3/h of demineralised water is needed. (For the material that need this quality with a production yield of 68t/h).

Cleaning and recirculation of degreasing baths:

For more detailed information, see 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, Chapter D.4.3.

Spent degreasing solution is cleaned, for example in an ultrafiltration device or a magnetic filter. The oily sludge may be used as reductor in the blast furnace. The treated degreasing bath is recycled. The figure below shows an example of a degreasing solution circuit.



Example of a degreasing solution recycling system

Main achieved environmental benefits

- reduction of alkaline chemical consumption
- reduction of water volume and sludge volume in the water treatment plant.

Applicability

New and existing plants with no space problems for pumps, pipes, tanks and so on.

Cross-media effects

Increased energy consumption.

Reference plants

voestalpine line 1 and 2, Aceralia line 2, Galtec 1 and others.

Operational data

Water consumption of $5m^3/h$ with the same consideration than before.

Economics

High investment and high operational costs.

Driving force for implementation

Environmental requirements.

Degreasing by burning oil in the heat treatment furnace:

Oil on the steel surface is burnt in the heat treatment furnaces. Alkaline degreasing is omitted.

Main achieved environmental benefits

- no emissions to water
- no generation of waste
- emissions to the atmosphere are lower than those generated in alkaline liquid degreasing.

Applicability

- new and existing installations
- when requirements for surface cleanliness and zinc adhesion are not very high.

Cross-media effects

Air emission through burning of oil rest.

Reference plants

Galtec 1

Operational data

It might still be necessary to have a degreasing section before the furnace for some high quality appliances. The furnace is not as easy to control as a radiant tubes furnace.

Economics

Investment and operative costs are reduced because there is no need for preceding sections. It is cheap on operation and installation.

Treatment of alkaline wastewater:

For a description, see the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapter D.4.5.

Main achieved environmental benefits

Reduced emissions to water.

Applicability

New and existing plants.

Degreasing vapour collection and treatment:

Vapours generated by degreasing are collected by means of an exhaust device and subject to a scrubber or demister for abatement. Wastewater originating from scrubbing is subject to water treatment.

Main achieved environmental benefits

- reduction of fugitive emission
- reduction in degreasing fume emission.

Applicability

- new and existing plants with degreasing devices
- existing plants with no space problems.

Cross-media effects

- scrubber: water consumption (evaporation) and sludge generation in water treatment plant
- demister: depending on the cleaning technique used, treatment of spraying water or solvents.

Reference plants

Several, including Jenn An, Taiwan, China.

Operational data

5m^3/h of recirculate water (evaporate) for a production yield of 66t/h.

Economics

Medium investment.

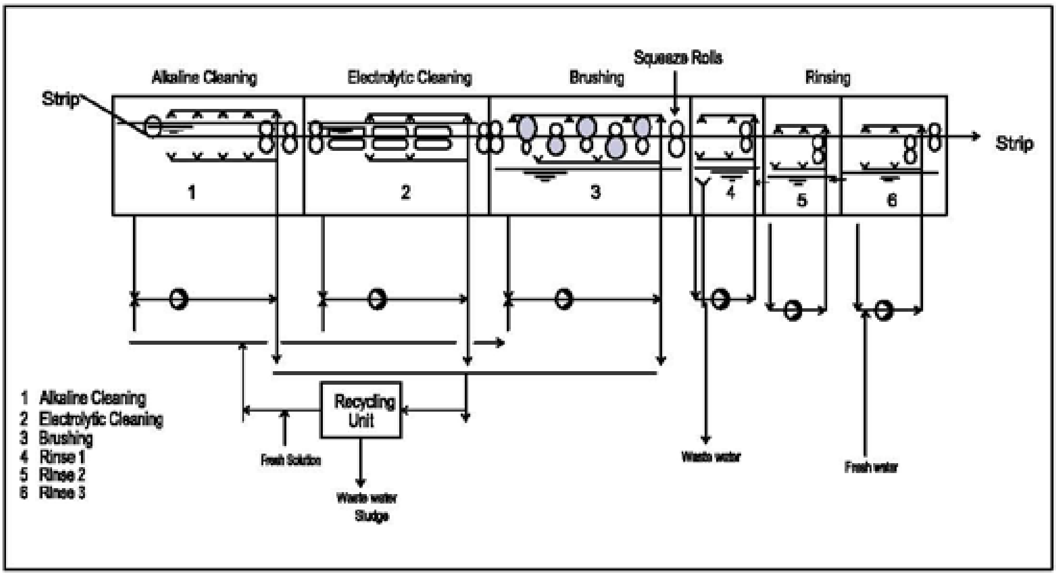
Driving force for implementation

Local conditions or requirements from local authorities that lead to implementation.

Using squeeze rolls:

The remaining degreasing solution or rinse water on the steel strip is removed from the strip by squeeze rolls before leaving each treating section. This will assure that dragout of solution into next section is minimised and loss of chemicals and contamination of rinse water is also minimised.

The figure below shows an example of a chemical pre-treatment section of a hot-dip galvanizing line for sheet using squeeze rolls and cascade rinsing (for efficient rinse water use).



Chemical pre-treatment section for a sheet hot dip coating line (example)

Main environmental benefits

- reduction of raw materials consumption
- reduction of wastewater volume and of sludge in the wastewater treatment plant.

Applicability

New and existing plants with degreasing and rinsing sections.

Cross media effects

None.

Economics

The initial investment in not so high and the operating cost is low.

Post treatments

Cleaning and reuse of phosphating solution:

The phosphate solution is filtered while recirculated. A small amount of exhausted solution is discharged from time to time and treated externally. The wastewater from the rinsing section is also treated externally in the water treatment plant. This treatment may be carried out off site.

Main achieved environmental benefits

- reduction of phosphating chemical consumption
- reduction of water outlets and volume of sludge in the water treatment plant.

Applicability

New installations and existing ones, if space does not pose a problem in revamping.

Cross-media effects

Energy consumption.

Reference plants

voestalpine

Economics

Investment costs are high, operating costs are medium.

Cleaning and reuse of chromating solution:

The chromium solution is filtered while recirculated. Exhausted solution is discharged from time to time and treated externally in the water treatment plant. This treatment may also be carried out off site.

Main achieved environmental benefits

- reduction of chromium chemical consumption
- reduction of water outlets and volume of sludge in the water treatment plant.

Applicability

New and revamped lines if no space problems.

Cross-media effects

Energy consumption.

Reference plants

voestalpine

Economics

Investment costs are high, operating costs are medium.

Covered process baths and storage tanks:

Storage tanks and chemical treating bathes are covered (extraction system) to collect emissions of fumes and aggressive waste air.

Main environmental benefits

- prevention of fugitive releases of chemical fumes
- reduction in exhaust air volumes.

Applicability

New and existing plants.

Reference plants

voestalpine lines 1 and 2, Aceralia line 2.

Using reverse osmosis to produce deionised water:

For preparation of chemical treating solutions and for rinsing water deionised water is required. This was produced in former times by desalination through ion exchange filters. As these filters need chemicals and water for regeneration as well as they produce regeneration brine.

Main environmental benefits

Reduction of chemicals consumption and avoidance of higher emissions in the natural waters.

Applicability

New and existing installations if is necessary to change the deionised unit.

Reference plant

voestalpine lines 1 and 2.

Cross media effects

None.

Economics

Investment costs are high, operational costs are medium.

Driving force for implementation

Environment and savings

Finishing

Collection and treatment of skin pass/temper solution:

Used solution, containing zinc particles and anti-corrosion compounds, is send to the water treatment section. The water could be recycled for the same or other purposes. Spent emulsion generated from tempering should be collected and send for water treatment.

Main achieved environmental benefits

Reduced water pollutant load (95%).

Applicability

New and existing plants that use skin pass.

Cross-media effects

None.

Reference plants

Galtec, Aceralia line 2, voestalpine HDG 1 and 2.

Economics

High investment costs, medium operation costs.

Driving force for implementation

Environmental requirements, cost requirements, yield increase and quality requirements.

Wastewater treatment

Generally, wastewater treatment plants treat not only the water from coating plants but also all the effluents generated in the rolling facilities. These plants normally consist of three different circuits: a chromic water line, oily water line and the general wastewater line.

Chromic water line:

The function of this circuit is to remove the chrome ions in the water, mainly, the Cr(VI), due to its higher toxicity, and the Cr(III). In the treatment plant the Cr(VI) is reduced to Cr(III) with sodium bisulphite or ferric chloride; the latter is preferable due to the much smoother reaction conditions obtained regarding pH, as the bisulphite reaction requires a much lower pH, thus entailing a higher acid consumption.

The following reaction takes place: Cr^{6+} + 3 Fe^{2+} ----------> Cr^{3+} + 3 Fe^{3+}

In the following stage the Cr^{3+} precipitates due to a pH increase obtained by addition of hydrated lime. Cr^{3+} + 3 OH^{-} ----------> 3 $Cr(OH)_3$

The ferric hydroxide precipitates simultaneously with the chromic hydroxide. The slurry obtained is treated in a decanter, inerted with milk of lime and subsequently passed through a press filter. Treatment with a polymer to achieve flocculation is also possible.

Main achieved environmental benefits

Reduction of chromium emission with effluent.

Applicability

New and existing plants.

Oily water circuit:

The aqueous effluents from those facilities where the strip is degreased prior to the coating processes are transferred to a neutralisation tank. Neutralisation is achieved through the addition of hydrochloric acid. If acidic wastewater from other processing steps (e.g. acidic rinse water) that cannot be recirculated is available, this may be used for neutralisation. After this step, the effluents enter a homogenisation tank and, subsequently, a coagulation and flocculation section.

Coagulation is achieved through the addition of ferric chloride and hydrochloric acid and flocculation by means of a treatment with polymers such as aluminium polychlorid and other types of polyelectrolyte.

From the flocculation tank, the effluent goes to a flotation tank where three phases are separated:

a. flocculated oily slurries
b. sediment slurries
c. water, to recycle.

The flocculated oily slurries float as foam, by the injection of pressurised water through the bottom of the aero-floater. The air absorbed by the water is released with depressurisation, forming small bubbles that adhere to the flocculated oily slurries making them float as a foam, subsequently removed by means of a suitable mechanism.

Other option/treatment of spent degreasing solution

The basic emulsion could also be treated in a central plant. First, there is a separation in three phases by means of gravity. The upper phase is treated in an oil centre. The middle phase is treated in an emulsion centre. The bottom phase consists of sludge and is treated separately. By means of ultrafiltration, emulsions are separated in water and oil. The water part is treated in a conventional biological plant to reduce COD.

Main achieved environmental benefits

Reduction of oil emission with effluent.

Applicability

New and existing plants.

Economics

Investment cost is very high and operational costs are high. However, environmental performance is also very high.

Driving force for implementation

Environmental requirements.

General wastewater circuit:

The wastewater treatment process consists of a flocculation with subsequent filtering and cooling. To improve the removal of oil and solid particles, a small amount of coagulating agent and polyelectrolyte is added to produce a microflocculation.

The water and the flocculi are sent to a battery of two-layer sand and anthracite filters that retain the particles formed. The filtrated water is transferred to cooling towers and the slurries retained in the filters are removed and passed through a press filter for subsequent recycling.

Main achieved environmental benefits

Reduction of pollutants in effluent.

Applicability

New and existing plants.

Operational data

Substance	Concentration in mg/l[1]	Type of sampling	Measurements in 1998 Operator/Comp. authority
Fe	1.5	Qualified random sample	28/5
Oil	0.2	Qualified random sample	28/5
Suspended solids	10	Qualified random sample	28/5
Cr	<0.006	Qualified random sample	28/5
Ni	0.01	Qualified random sample	28/5
Zn	0.04	Qualified random sample	28/5
Plant: BREGAL, Bremen [1]Mean values of the qualified random samples from 1998. Wastewater volume: 135,549m[3]			

Pollutant concentrations in water discharge from treatment of wastewater from galvanization

Cooling water systems

Closed cooling water loop:

See also the 'Best Available Technique Reference Document on Ferrous Metals Processing', December 2001, chapters D.9.2.

Separate and closed cooling water systems with recooling of the water by evaporative towers or plate heat exchangers.

Main achieved environmental benefits

- saving natural resources
- reduction of energy consumption.

Applicability

New installations and existing installation in case of major modernisation.

Economics

Investment costs are high, operating costs are low.

Driving force for implementation

Site-specific issues will govern the choice of cooling system and applicability on existing plants.

Reuse of cooling water

Design a water circuit to reintroduce the cooling waters to this process or for another purpose.

Main environmental benefits

- saving natural resources
- reduction of energy consumption.

Applicability

New and existing plants.

Operational data

The recycling ratio of the cooling water can easily surpass 90%.

Economics

Investment costs are high, operating costs are medium.

Conclusions

GALVANIZING OF SHEET:

For the best available techniques in pickling, refer to the BAT chapter of cold rolling mills.

For degreasing operations in continuous galvanising plants, the following techniques are considered to be BAT:

- cascade degreasing
- cleaning and recirculation of degreasing solution; appropriate measures for cleaning are mechanical methods and membrane filtration as described in chapter 1.6.6 and chapter 1.7.4
- treatment of spent degreasing solution by electrolytic emulsion splitting or ultrafiltration to reduce the oil content; separated oil fraction should be reused, e.g. thermally; the separated water fraction requires treatment (neutralisation, etc.).
- covered tanks with extraction and cleaning of extracted air by scrubber or demister
- use of squeeze rolls to minimise drag-out.

The environmental impact from phosphating and passivation/chromating can be reduced by the following BAT:

- covered process baths
- cleaning and reuse of phosphating solution
- cleaning and reuse of passivation solution
- use of squeeze rolls
- collection of skinpass/temper solution and treatment in wastewater treatment plant.

For cooling (machines etc.), separate cooling water systems operating in closed loops are considered BAT.

Wastewater arises in sheet galvanising from the chemical treatment sections and from rinsing operations. Wastewater also arises from strip cooling, contaminated by abrasion dust, and from the water sprays which are used to keep working rolls in the skin pass mill clean and which is contaminated by Zn-containing abrasion dust and lubricating oil. These wastewater streams require treatment by a combination of sedimentation, filtration and/or flotation/precipitation/flocculation. The techniques described in this report or equally efficient combinations of individual treatment measures are considered BAT. The associated pollutant concentrations in the effluent are:

SS:	< 20	mg/l
Fe:	< 10	mg/l
Zn:	< 2	mg/l
Ni:	< 0.2	mg/l
Crtot:	< 0.2	mg/l
Pb:	< 0.5	mg/l
Sn:	< 2	mg/l

With some of the existing continuous water treatment plants, a zinc level of <4mg/l is all that can be achieved. In these cases the best option is to switch to batch treatment.

BATs relating to iron and steel production, general processes and techniques

Water and wastewater management

In an integrated steelworks, water is used for direct and indirect cooling, gas cleaning, scale breaking and washing operations, including waste gas cleaning with scrubbers.

There can be various water systems in operation: completely closed, semi-closed or open circuits. There are only a few completely closed loops. Closed circuits can be used for cooling circuits operated with demineralised or softened water at specific installations, such as for continuous casting moulds or at boilers in power plants, which are generally cooled through an exchanger water/water. Here the second circuit of water is used as a semi-closed circuit with a cooling tower.

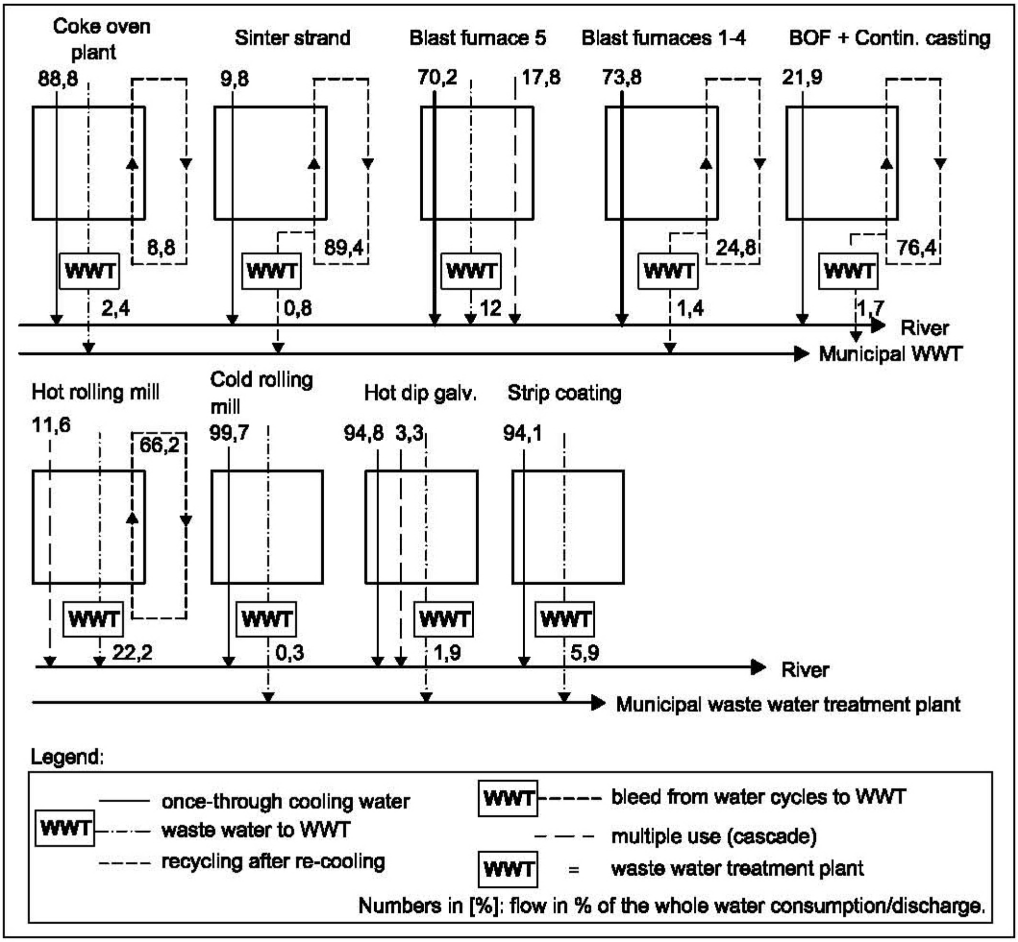
The following are three examples where semi-closed systems are used:

- in cooling towers for decreasing the water temperature. There is a need to bleed off a small discharge flow to limit the salt concentration in the water preventing the depositionof these salts and consequently corrosion and further possible leakages.
- for the recycling of wastewater after treatment for further uses not requiring such high quality water as for the first use. Since some undesirable substances can build up, a small amount of water has to be bleed off and lead to a wastewater treatment plant before final discharge. This amount needs to be replenished with freshwater.

- for process water which can be led in a close cycle. Since some undesirable substancescan build up, a small amount of water is led to a wastewater treatment plant beforedischarging. This amount needs to be replenished with freshwater.

The water management in an integrated steelworks primarily depends on local conditions, above all on the availability and quality of freshwater and on legal requirements.

The figure below gives an example of water management with an indication of the water treatment of an integrated steelworks with almost unlimited freshwater availability, thus explaining the presence of once-through cooling systems, resulting in a specific water intake of more than 100 - 200m³/t of steel. This is valid for plants close to large bodies of water, for example, large rivers.



Example of water management of an integrated steelworks at a location with a high surplus of freshwater availability

A driving factor for steadily improving the intake and outlet of water are the costs. The costs for wastewater treatment and releasing costs based on legal tax on discharging water into the municipal system can be considerable.

Another cost-related factor is that the water taken from the aforementioned bodies should undergo a conditioning step before it can be used, depending on the water quality for many applications. Furthermore, the pumping of such heavy water flows requires much energy. For these reasons, water use has been constantly reduced since 1980.

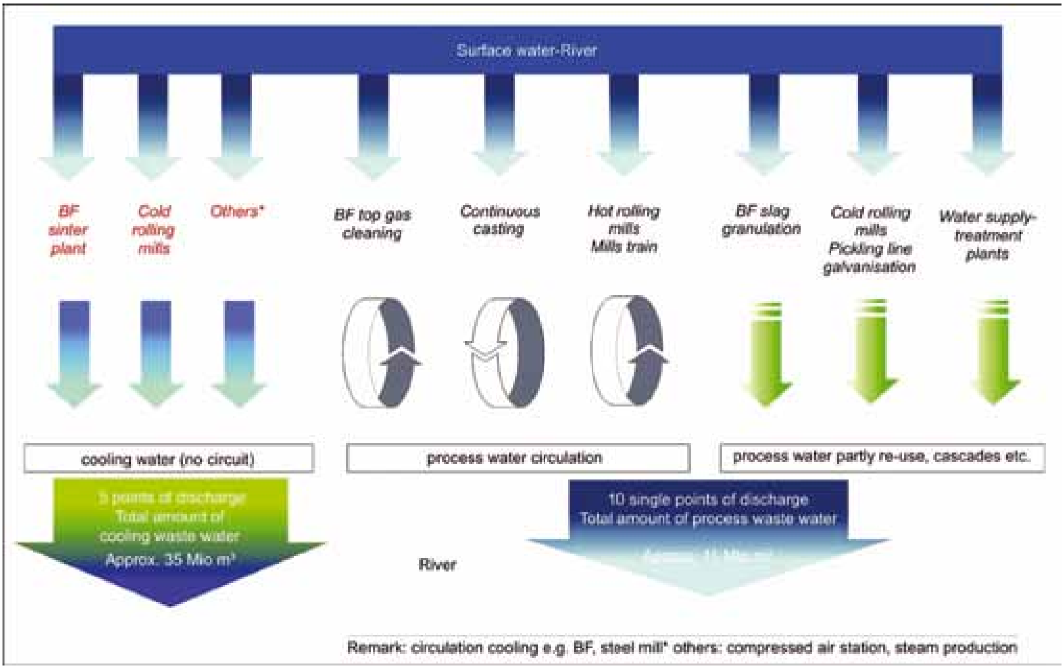
In particular, at sites with very low freshwater availability, where the water demand should be covered by groundwater or spring water, there may be a need to reduce water consumption intensely. In such cases, the specific water consumption can be lower than $5m^3/t$ of steel and the interdependencies can be much more intensive.

The table below illustrates a comparison between the intake water requirements of a once-through system and a system involving extensive recirculation in a typical integrated steelworks. The extensive recirculation in indirect and direct cooling systems reduces the total water intake to 2.4% of the requirement of the once-through system.

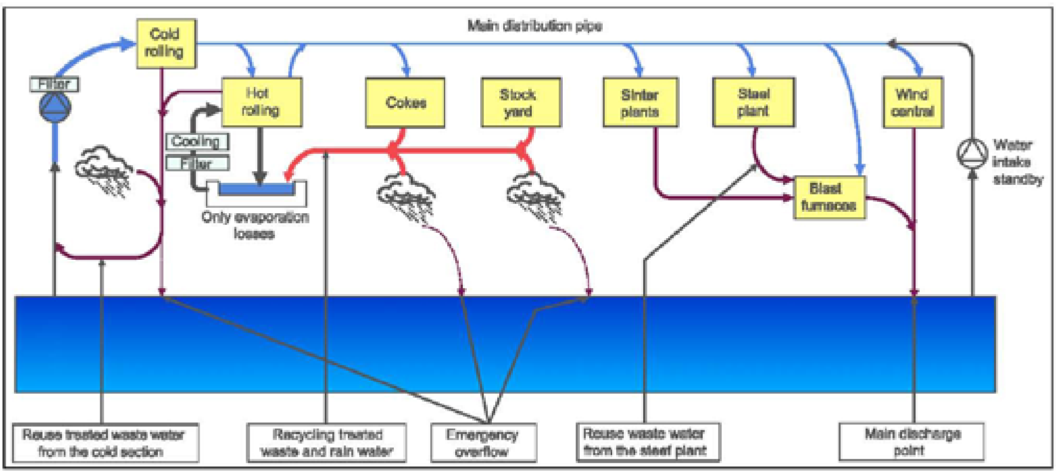
Water use	Quality	Water intake			
		Once-through system		Extensive recirculation	
		m^3/min	% of total	m^3/min	% of total
Indirect cooling	General	675	70.7	7.4	32
Direct cooling	General	265	27.8	6.2	26.8
Process water	Low grade	7.7	0.8	5.1	22.1
Potable water	High grade	1.5	0.2	1.5	6.5
Evaporation losses	4.8	0.5	2.9	12.6	
Total	954	100	23.1	100	
Note: It is not known if this data also includes the water used in downstream operations.					

Comparison in water intake required for integrated steelworks with once-through systems versus extensive recirculation

The following two figures show other examples of two different global systems from integrated steel plants.



Example for the water management of an integrated steelworks with separate circuits



Example for the water managment of an integrated steelworks using a cascade system

In the example plant depicted, the overall quantity of water in 2005 is nearly 1.2 billion m³/year. The recirculation rate in this case is 97.2% and only 2.8% need to be replenished with freshwater. The discharge as wastewater is only 1.2% and the rest are losses of about 1.6%. As a result, the water intake is about 3.16 m³/t crude steel.

Techniques which led to a reduced water intake and a minimised amount of discharged wastewater in the aforementioned case include:

- avoiding the use of potable water for production lines
- increasing the number and/or capacity of water circulating systems when building new plants or modernising/revamping existing plants
- centralising the distribution of incoming freshwater
- using the water in cascades until single parameters reach their legal or technical limits
- using the water in other plants if only single parameters of the water are affected and a further usage is possible
- keeping treated and untreated wastewater separated. By this measure it is possible to dispose of wastewater in different ways at a reasonable cost.
- using rainwater whenever possible.

Techniques to control releases to water from raw materials handling, blending and mixing

Rainwater runoff from all open areas, but in particular from ores, coal and raw material stocking areas, will contain suspended solids. This rainwater runoff should be intercepted and the suspended solids removed by settlement or other techniques. Arrangements should be made for monitoring the quality of the water discharged from the storage and blending areas where such discharges are in the vicinity of potentially vulnerable receptors.

Areas for the handling and storage of purchased scrap are potential sources of contaminated effluent due to the leaching of oil and chemicals by rainwater. The scrap should be stored on hard surfaced areas with an impermeable surface and an appropriate drainage system, including an interceptor trap prior to discharge, unless the environmental risk can be shown to be negligible (for example, storing clean scrap).

Achieved environmental benefits

A reduction of pollution to water is an environmental benefit of this technique.

Example plants

All UK iron and steel plants.

Monitoring the discharge of wastewater

Monitoring the discharge of wastewater includes taking representative samples of wastewater and analysing them. A great variety of standardised procedures exist for sampling and analysing of water and wastewater.

Taking samples can be done by:

- a random sample, which refers to a single sample taken from a wastewater flow
- a composite sample, which refers to a sample taken continuously over a given period, or a sample consisting of several samples taken either continuously or discontinuously over a given period and blended
- a qualified random sample, which refer to a composite sample of at least five random samples taken over a maximum of two hours at intervals of no less than two minutes, and blended.

The emission concentration in the wastewater which has been reported for relevant processes in this document refers either to qualified random samples or to 24-hour composite samples. The associated BAT-AELs, therefore also refer to random samples or to 24-hour composite samples.

Conclusions

BAT for wastewater management includes prevention, collection and separation of the wastewater types, maximising internal recycling and applying an adequate treatment for each final flow. This includes techniques that use oil interceptors, filtration or sedimentation.

Appendix C: References

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worldsteel
ASSOCIATION

World Steel Association

Rue Colonel Bourg 120
B-1140 Brussels
Belgium

T: +32 2 702 8900
F: +32 2 702 8899
E: steel@worldsteel.org

C413 Office Building
Beijing Lufthansa Center
50 Liangmaqiao Road
Chaoyang District
Beijing 100125
China

T: +86 10 6464 6733
F: +86 10 6464 6744
E: china@worldsteel.org

worldsteel.org