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Total water management approach in steel industry

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ABSTRACT

Water, due to its high specific heat capacity is considered to be an extremely attractive means for heat transfer (cooling) in industrial processes. A total water management plan for steel industry is presented here, taking into account local conditions, legal requirements and above all the availability of fresh water. The alternative water inlets which may also be used are presented here. Since the recovery and reuse of the discharged water from water treatment plants (WTPs) is the best practice in managing the cooling circuits at present, treatment technologies such as ultrafiltration, nanofiltration and reverse osmosis are also presented. The examination of best available techniques (BAT) showed that steel industry should establish fully automated WTPs where the water is recycled. The installation of a sewage treatment plant to treat wastewater that is produced in a steel industry during its operation time was found to be an environmentally benign practice especially when the treated sewage water was used for irrigation. It can be concluded that future efforts must be oriented towards sustainable management of water resources which will enable recycling and reuse of water to a level of 'zero discharges' in order for the industry to remain competitive and environmentally friendly.

Keywords: Sustainable water management; BAT (best available techniques); Recovery and reuse of water; Reverse osmosis; Ultrafiltration

1. Introduction

Due to its high specific heat capacity water is considered to be an extremely attractive means for heat transfer in industrial processes. Cooling is an essential element in many industries especially in steel production, which is considered as water-intensive process. The purpose of the implementation of a total water management plan in steel sector is to establish a framework for the protection of water which prevents further deterioration and protects and enhances the status of aquatic ecosystem, promotes sustainable water management based on a long-term protection of available water resources and ensures the progressive reduction of discharges.

For the implementation of the Directive IPPC (Integrated Pollution Prevention and Control) steel sector is advised to use Best Available Techniques (BAT) Reference Documents (BREFs) proposed by European Commission in order to reduce their environmental impacts.

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According to the new New Industrial Emissions Directive the Best Available Techniques Reference Documents (BREFs) are, in essence rendered legally binding, thus abolishing flexibility, one of IPPCD's fundamental principles. All installations falling under the scope, are allowed to operate only if they hold a permit which, inter alia, includes emission limit values (ELVs) strictly in accordance to the best available techniques associated emission levels (BATAELs) in the relative BREFs.

EC proposal raised strong objections from member states and organizations (Business Europe, Eurelectric, Euracoal), because of the abolishment of IPPC's flexibility principle, the contradiction in timing with other EU initiatives (2016 versus 2020 of "the green package" and NEC Directive, not allowing to "optimise across multiple goals") and the enormous costs for compliance, mainly for existing plants and consequent issues of security of supply.

A mini steel mill consists of meltshop and rolling mills. At the meltshop, steel is produced in the form of prisms (billets/slabs). The basic production stages of the steel making process include melting of steel scrap in an electric arc furnace, secondary metallurgy (fine adjustments to steel composition) and continuous casting of molten steel. In the rolling mill the billets/slabs are fed in the reheating furnace and then through a succession of stands a range of steel for the reinforcement of concrete is produced, either ribbed or smooth and in straight bars and coils or in flat final products (coils).

Water treatment plants are auxiliary plants and provide high quality cooling water to the steel production. These plants usually consist of indirect and direct circuits where the water through clarification steps (sedimentation, filtration) is cooled via cooling towers or heat exchangers. In order to minimize the consumption of water, the water is recycled to the maximum level.

The scope of the installation of water treatment plants is to provide high quality cooling water to the steel sector through the recirculation of water to the maximum level, to inhibit scale and corrosion in the equipment with the aid of the appropriate chemical treatment, to remove and disperse contaminants/solids and to control microbiological growth.

2. Impact of water quality on water management

The water in the WTPs must retain a certain quality in order to avoid corrosion, scaling and biofouling conditions. From the viewpoint of pollutant control a high recycling ratio is preferred, however, factors such as build-up of hardness and conductivity require that an optimum recycling ratio is determined from a total water system analysis [1].

Microbiological growth, deposits of scale and corrosion tendencies are responsible for great losses of energy and water. In Fig. 1, the losses of energy due to deposits are presented.

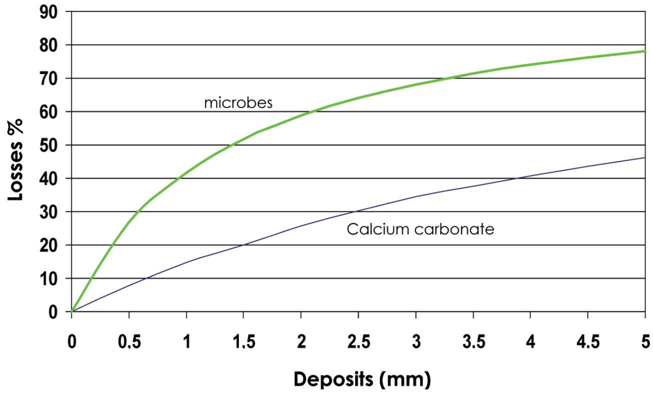

Fig. 1. Percentage losses of energy due to the width of deposits. Source: Kemmer [2].

The two most important indexes for measuring the scaling / aggressive tendency of cooling water are Ryznar Stability Index (RI) and Langelier Saturation index (LSI). The RI is a method of quantifying the scale forming or corrosive effect of the water. It is based upon the pH of the water and the pH at which water cannot hold additional calcium in solution (pH). The LSI is an equilibrium model derived from the theoretical concept of saturation and provides an indicator of the degree of saturation of water with respect to calcium carbonate. In Table 1, scaling and aggressive tendency of water is shown depending on the combination of the values of the two indexes.

3. Water sources in steel industry

Steel production is an energy- and water-intensive process: large quantities of water are used for cooling, process and environmental/technical applications.

The alternative sources of water that the steel sector could use taking into consideration the availability of each source are: surface water, well brackish water,

Table 1
Water behavior according to LSI and RI. Source: Sharshar [3]

LSI	Water behaviour	RI
–2÷–3	Very strong aggressiveness	>0
–1÷–2	Strong aggressiveness	8÷9
0÷–1	Moderate aggressiveness	7÷8
0	Stable water	6÷7
0÷+1	Lightly scaling water	6÷5
+1÷+2	Moderately scaling water	5÷4
+2÷+3	Strongly scaling water	4÷3
>3	Scaling conditions extremely severe	<3

city water (potable water), seawater, treated water from sewage plant or even rain water. The proportions vary greatly from one plant to another. The selection of the best available technology for the treatment of the inlet water depends on the origin of water.

As far as seawater and brackish well water is concerned, the inlet source must be treated via appropriate reverse osmosis. It is the reverse of the normal osmosis process by using pressure to force a solution through a membrane, retaining the solute on one side and allowing the pure solvent to pass to the other side [4].

If the source of inlet water for WTPs is city water or rain water then the treatment could become cheaper and simpler. The rain water is suggested to be collected to one collecting tank in the correct shape and volume in order to allow the complete separation of sand and other dirty particles settled on the surface. The recovered water could be used for make up to the first step of treatment. The treatment is not difficult and is a low cost investment. This option is not significant in terms of quantity therefore it is suggested to use it additionally with another source.

In order to use treated water from a sewage plant, steel industries must take into consideration the quality of the water discharged form the sewage plant and then install the appropriate treatment technology. Usually sewage effluents possess high organic load, therefore Ultrafiltration (UF) technology could be installed. UF is a pressure-driven barrier to suspended solids, bacteria, viruses, endotoxins and other pathogens to produce water with very high purity and low silt density. It serves as a pre-treatment for surface water, seawater, and biologically treated municipal effluent before reverse osmosis and other membrane systems. UF is also used in industry to separate suspended solids from solution. Ultrafiltration is not fundamentally different from nanofiltration, except in terms of the size of the molecules it retains.

After the first step of treatment the water is pumped to the WTPs in order to be cooled and then is fed in the steel production (meltshop, rolling mills). In the WTPs it is strongly suggested to recirculate the water and any discharges should be reused in the beginning of the process of water treatment. The above mentioned circle of water is presented in Fig. 2.

4. Water treatment plants

The proposed best available techniques that are suggested for the steel sector concerning the treatment of water are listed below according to the European Commission:

- Closed loop water cooling system for the cooling of furnace devices. The minimization of consumption and discharge by operating closed loops with recirculating rates of >95% is considered BAT.
- Recycling of cooling water as much as possible.
- Precipitation/sedimentation of suspended solids
- Removal of oil in skimming tanks or any other effective device. Oils are found in the water flowing out of rolling mills particularly and originate from lubrication of mechanical elements. The oils should be separated [1,4–6].

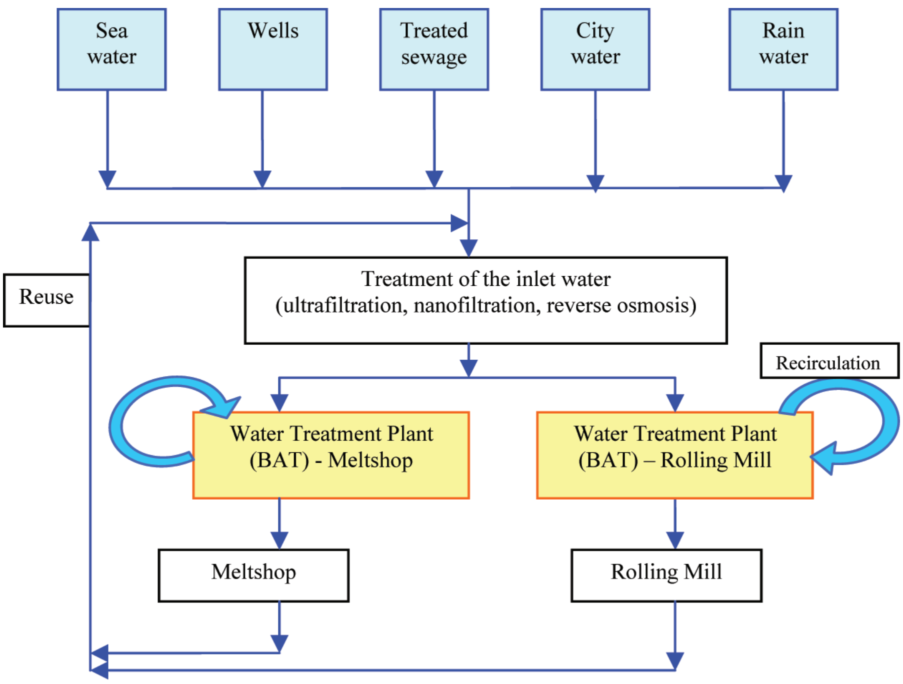

Fig. 2. Circle of water in a steel industry.

The examination of best available techniques (BAT) for this purpose showed that steel industry should establish fully automated water treatment plants (WTPs) where the water is recycled.

The installation of water treatment plants in steel sector for indirect and direct cooling of the equipment and the products is the heart of the water management system. These plants must be especially designed in order to minimize the consumption of the water to be reinstated.

The WTPs consist of indirect open and closed circuits and direct open circuits. In the indirect open and closed cooling circuits water is not in contact with products and is usually used for cooling furnaces, heat exchangers and the mould of the continuous casting machine. Water used for indirect cooling is contained in a closed system and is far less prone to contamination, however, some water must be removed from the circuit to prevent excessive water hardness and build up of suspended solids. The water after cooling the equipment is fed to cooling towers for the reduction of thermal load. In direct open circuit water is in contact with products and is usually used for cooling the rollers and the products in all stages of the production line. The water is polluted mostly with suspended particles of mill scale, particles and in some cases oil. For this purpose, the water which gets in contact with the products is subjected to a clarification process, which reduces to a minimum the water losses. Cleaned water after filtration is recirculated to the cooling towers and back to system as shown in Fig. 3.

For the removal of solids/mill scale it is suggested to use:

- Settling basins, which are a simple, low maintenance means of removing solid particles from liquid by gravity. After a preliminary stage of chemical coagulation and precipitation using a polymeric flocculant, the velocity of the waste water stream is reduced as it passes into a large volume basin where settling occurs. Sufficient retention time and regular sludge removal are important factors that determine the success of this method.
- Clarifiers, which are more effective than settling basins for the removal of suspended solids, require less space and provide for centralised sludge collection. Chemical aids can be used to enhance solids removal, although chemical pre-treatment and sludge removal systems both require regular maintenance.
- Filtration, which is a highly reliable method of waste water treatment, capable of removing suspended solids and unwanted odours and colour. The advantages of filtration are the low solids concentration that can be achieved, low investment and operating costs, modest land requirements and low levels of chemical discharge. Some pre-treatment may be necessary if the solids level is greater than 100 mg/L. The most important variable in filter design is the width and depth of the media, although particle density, size distribution and chemical composition are also important in terms of media selection. The media selected depends on the filtration rate and may consist of sand, diatomaceous earth, walnut shells or, for concentrations below 5 mg/L solids, anthracite. All filters require regular back washing to prevent accumulation of solids in the filter bed [8].

The mill scale and the sludge from the settlers are suggested to be disposed to cement industry.

For the removal of oil it is suggested to use oil skimmers, which can be used to remove floating oil and grease from the water surface. Skimming efficiency depends on the density of the floated material and the retention time for phase separation, which varies from 1 to 15 min.

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%.

Oils and greases form oil skimmers are suggested to be disposed for regeneration or recycling [3].

5. Recovery and reuse of water

The recovery and reuse of discharged water is pre-

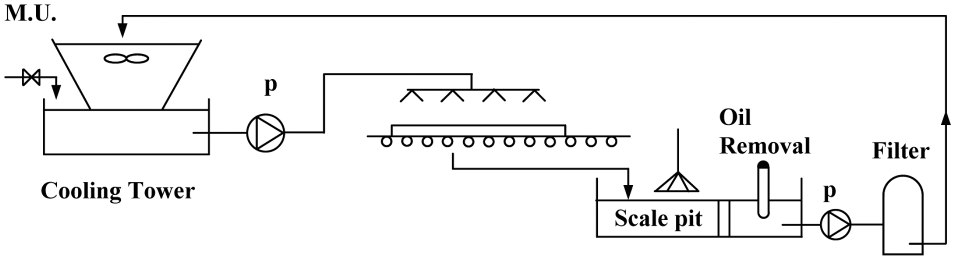

Fig. 3. Direct open circuit.

sented as best practice in managing the cooling circuits. It is strongly advised to collect all the effluents from the various sections of a steel mill to a basin and return them to the first step of the circle of water as it is shown in Fig. 3. The process is a preliminary treatment of the discharged water in order to reduce organic content and eliminate suspended solids with ultrafiltration so that afterwards may be treated as raw water.

Recovery of discharged water from indirect to direct system may also be considered as a good practice for overall water reduction as it is easy to implement. Since water in indirect systems is of good quality it will improve corrosion protection in direct systems [8].

6. Sewage treatment plants

Installation of a sewage treatment plant for the treatment of wastewater that is produced from the personnel of the steel industry may be suggested. Activated sludge process or MBR (membrane bioreactors) process could be used for this purpose and the treated wastewater may afterwards be used for irrigation.

The activated sludge process is a wastewater treatment method with an aeration tank where air or oxygen is introduced into the system to create an aerobic environment that meets the needs of the biological community. In the next stage a secondary sedimentation tank is used where activated-sludge solids separate from the surrounding water by the process of flocculation and gravity sedimentation. A part of activated sludge must be collected from the secondary clarifiers and pumped back to the aeration tank(s) so that the biological community needed in the wastewater stream is replenished [9].

Alternatively MBR technology could be used for the treatment of wastewater. The MBR process is an emerging advanced wastewater treatment technology that has been successfully applied at an ever increasing number of locations around the world. The MBR process involves a suspended growth activated sludge system that utilises microporous membranes for solid/liquid separation in lieu of secondary clarifiers.

7. State of the art in Greek steel industry

Environmental conscience and respect towards the human, cultural, and natural environment has led Greek steel industry to proceed to environmental investments in order to apply BAT, including inter alia automated water treatment plants for water processing, as already mentioned, where cooling water is recycled.

Generally Greek steel industry applies advanced control systems and uses BAT in order to minimize environmental strain and ensure maximum protection of its personnel and the community at large.

Environmental protection and sustainable development are a priority for the Greek steel industry. For this purpose, the companies invest on a yearly basis not only to meet legal requirements but to keep improving their environmental performance. The environmental management system of companies is in the certification process, according to the international standard ISO 14001:2004.

The Greek steel industry's large scale discharge of wastewater is affecting the quality of water in surface water bodies, rivers and ground water reservoirs. The Greek steel industry introspects on mechanisms to optimize water usage. The steel industry invests towards a green manufacturing process chain for reduced wastewater discharge. There is promise in the industry to change for the better. However, a supporting regime is required for their will to change into action. Understanding the issues faced by the industry and the authorities in working towards an efficient and sustainable water usage and disposal system and other issues will provide a holistic perspective related to water for industry and water from industry.

8. Conclusions

It can be concluded that continuous production of steel is intimately connected with the availability of large volumes of continuous and uninterrupted supply of fresh water. A sustainable water management plan must not rely to municipal water sources since their availability is not stable and they must be protected for the next generations. Therefore, future efforts must be oriented to sustainable management of water resources and to maximization of water recycling and reuse towards a level of 'zero discharges' in order for the industry to remain competitive and environmentally friendly.

For the reduction of water requirements the following statements can be made:

- In the light of the overall energy balance, cooling with water is most efficient
- For new installations a site should be selected for the availability of sufficient quantities of water in the case of large cooling water demand
- Where water availability is limited, appropriate technology that enables less water-consuming practices should be chosen
- In all cases recirculating cooling is an option, but this needs careful balancing with other factors, such as the required water conditioning and a lower overall energy efficiency.

Adopting a total water management plan in steel industry and an environmental management system for all the outputs from each water clarification step (scale, oils) will lead the industry to a cleaner production and industrial symbiosis.

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