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WATER RECLAMATION FROM WASTEWATER IN CLOSED CYCLES IRON AND STEEL PLANTS

1. INTRODUCTION

The iron and steel industry falls into the category of major water consumers as it uses 160–220 m^3/ton of steel. Old technology steel works applied open water cycles which resulted in a discharge of 100–180 m^3 wastes/ton steel. The wastewater systems presently used in most of the iron and steel plants, are partially closed cycles (fig. 1a), where the amount of wastewater discharge ranges from 6 to 15m^3 per 1 ton of steel. Figure 1b presents the fully closed cycle plant designed at this Institute, with practically no industrial effluent discharge. Based on this scheme the "Katowice" iron and steel plant and other industrial plants were designed as a fully closed cycle plant. The system can be applied at the existing steel plants.

In this note principles of designing the fully closed cycle steel plants are discussed.

2. THE KINDS OF WASTEWATER AND MAKE-UP WATER QUALITY

The sources of wastewater in the steel plants include: slimes from cooling cycles with surface cooling, slimes from cooling cycles with direct cooling, spent liquors from pickling and steel products surface treatment, rinse water from the chemical treatment of rolled products surface, water from fluming (scale from rolling mill plants, ashes from heat and power plant), wastewater from chemical processing of coal (from coke plant, and gas generating plant), wastewater from the ion exchanger regeneration, wastewater from maintenance shops such as: transport railway and workshops etc. sanitary wastes, rain water.

Water for industrial purposes in the steel industry should fulfill certain conditions, depending on the kind of application. Three kinds of waters are distinguished: the basic, the higher and the lower standard water.

Water of basic standard is supplied to the closed cycles, that use surface cooling installations. Water of higher standard is used for the supply of steam boilers, steel industry installations evaporative cooling, the supply of binary cycle (e.g. Heller cooler system), high pressure equipment at rolling mills etc. Water of lower standard is supplied to the closed cycles, that use direct cooling and to the dual cycles. The latter have several advantages, and are more frequently used at the steel industry. The best effects of improving the cooling conditions can be obtained with these cycles. In the first cycle, where water flows through the steel plant installations, water of the highest parameters and with the most effective corrosion inhibitors is applied, for example chromates can not be applied in normal cycles, because of the water protection.

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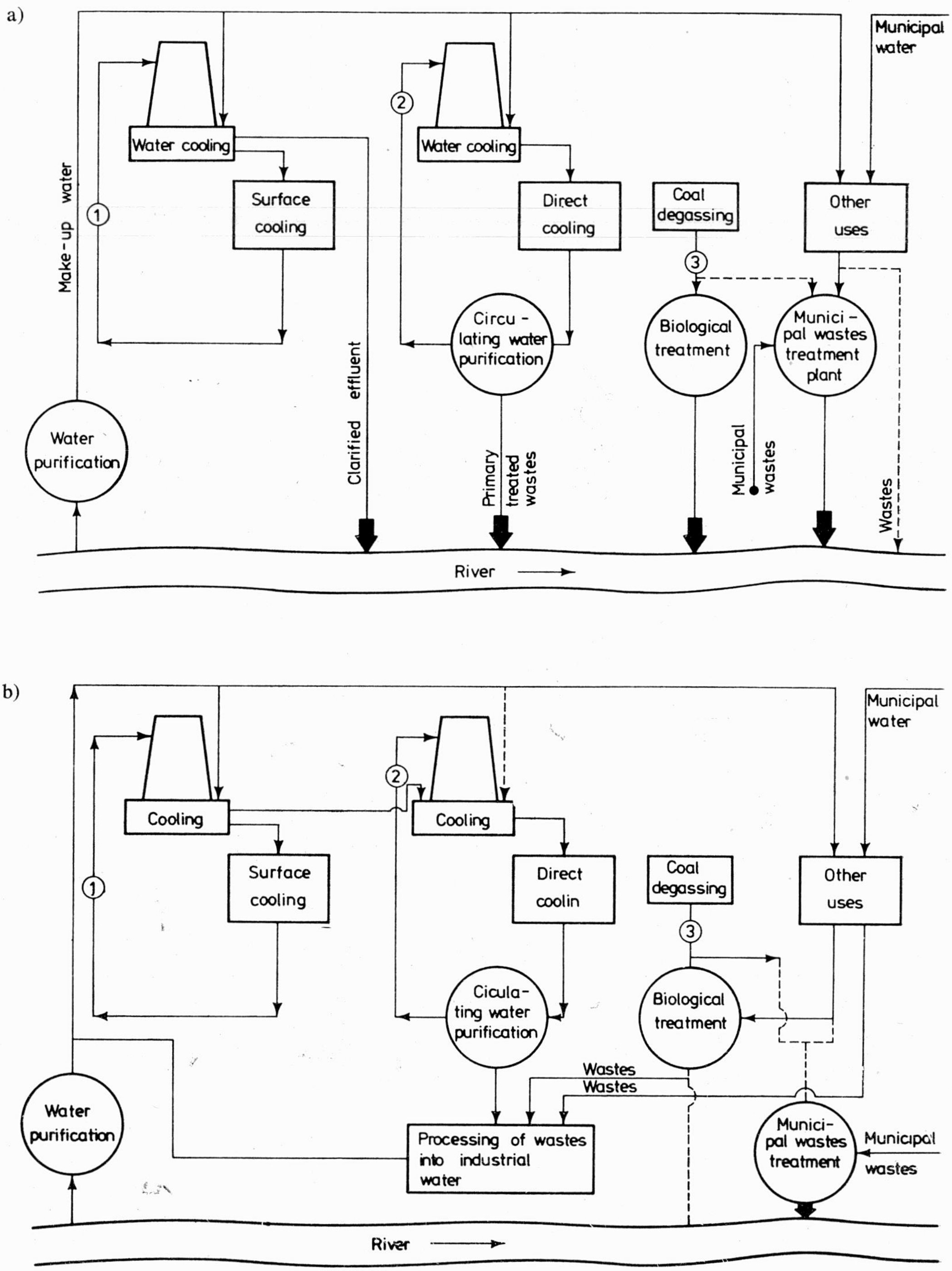

Fig. 1. Layout of water and wastewater management in partially closed cycle (1a) and in the fully closed (1b)

In the secondary cycle, water of worse quality can be applied, as the heat exchanger walls have low temperature.

The closed cycles where the surface cooling installations are used are the main receivers of make up water including the water reclaimed from steel plant wastewater. The reclaimed industrial water of basic standard for these cycle should fulfill the following requirements:

– the thermostability limit can not be smaller than 353 K (80°C) and the sediment precipitation coefficient should be as low as possible,

– the circulating water thickening coefficient should be higher than 2,

– water should not have corrosive properties against materials it is in contact with,

– the organic compounds content must be low, so as to unable the biomass development in the cooling cycles,

– water can not contain simultanously the ammonium ions and the substances from which these ions can be formed in the presence of phosphorus compounds,

– the water pH value should be in the range of 7.5–8.5,

– the suspended solids content should not exceed 5 mg/dm^3,

– the iron content should not exceed 0.2 mg/dm^3,

– the oil content should not be higher than 5 mg/dm^3,

– the sulphides and hydrogen sulphide content should not exceed 0.5 mg/dm^3,

– water should be properly disinfected.

As for allowable concentration of chlorides and sulphades present in the water reclaimed from wastewater, it depends on the circulating water thickening coefficient applied and on the corrosion inhibitors used. It can be generally stated, that the chlorides concentration in the circulating water should not exceed 600 mg Cl^-/dm^3, and the sulphates concentration – 1000 mg $SO_4^{=}/dm^3$.

The criteria for water of higher standard are given by the equipment producers, the lower standard water parameters are established based on local conditions.

3. SUMMARY OF TREATMENT REQUIREMENTS

At steel plants, where raw ore is taken to finished steel the closed cascade systems should be applied, utilizing the output from the surface cooling cycles for the supply of the direct cooling cycles. The output from the latter is partly directed to the processes where the nonreturnable water consumption takes place and partly to the industrial water reclamation plant. Whenever possible, dual cycles should be applied. For the removal of pollutants penetrating to water in the direct cooling cycles and during the technological processes, the application of adequate department treatment plants is necessary. The water desalting must be carried out, as the water gets concentrated in the cooling cycles. A spontaneous desalting process occurs, when the water is sprayed in the cooling towers and fan coolers and a part of the circulating water is discharged together with the sediments. Further desalting can be obtained by the application of standard water treatment (decarbonization and demineralization, reverse osmosis), by connecting the water cycles, by the application of evaporators and by introduction of the nitric acid for regeneration of ion exchanger instead of hydrochloric acid. In this country particular attention should be paid to the latter two methods. Many kinds of waters, especially those from the direct cooling, have specific physico-chemical properties allowing for their application in so-called joint cycles. For this purpose the "antagonistic" water properties are utilized, the mixing of waters results in better water quality in comparison with the separate water cycles. An example of this can be mixing of strongly alkaline waters from the ore sintering plant cycles with the circulating water from blast furnace gas purification plant with a particularly high content of calcium bicarbonate (fig. 2). Each of the above mentioned types of water is not stable and has a tendency to form scale deposits. Their mixing causes chemical reactions between the alkalies present in waters from the casting machines and the bicarbonates present in water from the blast furnace gas purification plant cycle. The reaction product is the practically insoluble calcium carbonate, which precipitates in the form of se-

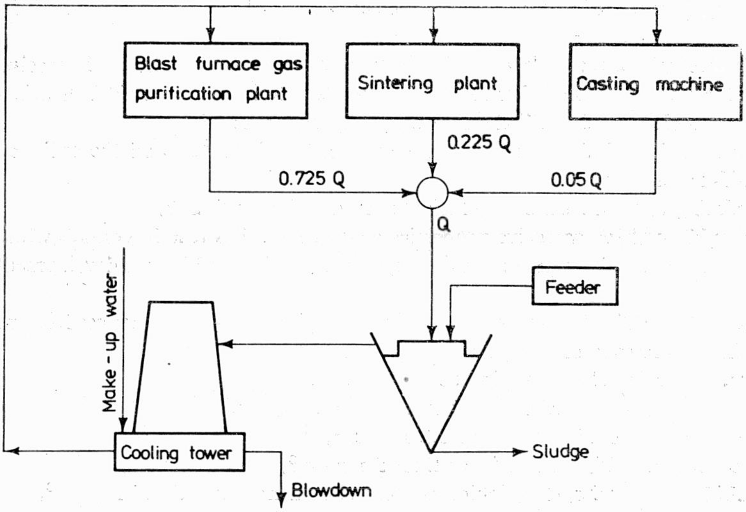

Fig. 2. The diagram of joining the cycles of blast furnace gas purification plant, sintering plant and the casting machines into integrated system

diment. It is also significant, that part of the salts present in the circulating waters, leave the environment in the solid form, that is as the $CaCO_3$ sediment; thus the decrease of the overall water salinity can be obtained, applying the method of joint water cycles.

The "antagonistic" physico-chemical properties of waters and steel plant wastewaters allow for the reuse e.g. rinse waters from rinsing the steel products, from their degreasing in the lye-phosphoric bath, the wastes from the neutralization from power plant ash fluming, etc.

The discharge from the regeneration of ion exchangers is a serious source of water salinity. In order to decrease salinity the hydrochloric acid used for the ion exchangers regeneration can be replaced by the nitric acid.

4. CASE EXAMPLES

A large transformer sheet rolling mill plant is the first fully closed cycle industrial plant in this country and has worked for several years. The plant is supplied with 150 m^3/h of make-up river water while some 2600 m^3/h of water circulates in the cooling cycles. For the steel plant heating furnaces the dual cooling cycles were partly applied. The make-up water is appropriately treated: for the desalting of water cycle a partial demineralization of make-up water is carried out, whereas the highly salinated wastewaters undergo evaporation. Some of the wastewater is processed into industrial water. This includes alkaline rinse waters from the metal sheet electrolytic degreasing, acid rinse waters from metal sheet pickling with sulphuric acid and the rinse waters from removing the MgO coat from the metal sheet surface as well as periodically, rinse waters from the filters at water treatment plant, prior to their purification from suspended matter in the horizontal sedimentation tank. Acid and alkaline wastewaters are jointly neutralized, clarified and filtrated before joining the main cooling water cycle.

Acid solutions from metal sheet pickling and the spent alkaline baths from the electrolytic degreasing are periodically discharged to the wastewater treatment plant together with the hydrated sediments produced at the water reclamation plant and with the prethickened spent-regeneration solutions from the ion exchangers. The wastes are then evaporated while sludge is disposed off at the dumps. The condensates are directed to the cooling cycle. The plant discussed has no discharge to the river which is of the potable water quality.

One of the large iron and steel plant is another example of a full closed cycle industrial plant. It is supplied with about 2,450 m^3/h make-up river water while over 92,000 m^3/h will be circulating in one open cycle and in 18 closed cycles. Wastewaters from the individual steel plant departments will be directed to the water reclamation plant and recycled.

5. SUMMARY

The iron and steel industry as one of the biggest water consummers has successfuly introduced the fully closed cycle of water use, where only sanitary wastes are directed to the biological sewage treatment plant and rain water is primary treated for river discharge. This solution has resulted in a very cost-effective water economy and in a proper protection of waters against pollution. It is assumed that the idea of closed water cycle iron and steel plant can be applied not only at the steel industry, but also at other branches of industry.