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SHORT COMMUNICATION

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CLEANER METALLURGICAL INDUSTRY IN SERBIA: A ROAD TO THE SUSTAINABLE DEVELOPMENT

Since the sustainable development has been a global and fundamental objecttive, a metallurgical industrial sector faces some of the most difficult sustainability challenges of any industrial sector. On the other hand, the metallurgical production in Serbia is a very important part of the economy. Due to present facilities and technologies, metallurgical companies face a great challenge to fulfill the requirements introduced by legislature referring to the cleaner production and sustainable development. The state of art in the production, facilities, pollution with some answers to imposed challenges is presented.

Key words: metallurgy; cleaner production; sustainable development.

Metallurgical industry has a very important role in Serbian economy. It covers approximately 10 % of the GDP, both in the primary production of metals/ /alloys and the production of metallic components (heavy machinery is not incorporated). In the latter case, facilities for casting, forging, rolling, heat treatment, surface treatment and welding are parts of technological processes. For example, during 2006 26.17 % of total Serbian export was related directly to the production of steel and non-ferrous metals and their alloys [1].

STATE OF THE ART AND THE CHALLENGES

Metal production was one of the leading industrial activities from early days (Neolithic period!, 7000-5500 BC) of Serbian economy. It was characterized by a variety of produced metals and its alloys (iron and steel, Cu and Cu alloys, Zn, Pb, Al alloys, Ag, Au, Mg and Mg alloys - maximal annual production is given in Table 1), diversified production locations, different scales of capacities and technologies, *etc*. Therefore, the industrial development resulted in the consumption of large amounts of energy and raw materials usually accompanied by devastation of the resources and the environment (use of fossil fuels, pollution of water, air and soil, waste disposal, *etc*). The main sources of the pollution in metallurgical industry are the emission of powder particles (dust), the emission of gaseous pollutants, an inadequate treatment and disposal of the solid waste, the emission of polluted waters without any treatment, a low level of energetic efficiency.

Table 1. Maximal annual production of metals in Serbia

Metal	Company/Location	Year	Production t
Steel	USS Serbia/Smederevo	2005	2100000.0
Copper	RTB BOR/Bor	1988	180241
Zinc	Trepča/Kosovska Mitrovica	1988	48500.0
	Zorka/Šabac	1981	36756.0
Cadmium	Trepča/Kosovska Mitrovica	1988	156.4
	Zorka/Šabac	1988	102.0
Lead	Trepča/Kosovska Mitrovica	1975	89138.0
	Farmakom MB/Zajača	2006	9000.0
Silver	Trepča and Bor	1986	177.0
Bismuth	Trepča/Kosovska Mitrovica	1975	111.4
Anhtimony	Farmakom MB/Zajača	1965	2768,0
Gold	RTB BOR/Bor	1990	4.7

Iron and steel production in Serbia is related solely to steelworks US Steel Serbia in Smederevo. It is an integrated factory with a technological process starting from raw materials (iron ore, coke and limestone) and finishing with hot rolled strip and/or cold

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rolled sheets, at one location. The annual production is close to 2 million of tons of final products (steel sheet and strip). Some of the production is covered by the production of crude iron in both blast furnaces and crude steel in converters, while the rest is from other factories. Within the process, air pollutants are being released at 90 different positions (not all are in an operating mode at the moment). The largest number is related to agglomeration (34) and converter steel plant (32), while the smallest is related to cold rolling mill (11), both blast furnaces (only 8!), Hot rolling mill (4) and power station (1). Approximately 32000 m^3 of off-gases are generated per each ton of crude iron and steel. Dominant components are carbon monoxide (≈11 kg CO/t of final product), sulfur dioxide (≈4.5 kg SO_2/t of final product) and nitrogen oxides (≈0.7 kg NO_x/t of final product). The content of the dust in the off-gases depends strongly on the quality of the input raw materials and the technological process itself. It is estimated that during the production of 1 ton of iron, 100-120 kg of dust, mud and waste iron oxides are generated (2-3 g per each m^3 of waste gases). Solid waste consists of metallurgical slags, iron slags generated in blast furnace 450-550 kg per tone of produced iron and steel slags generated in three oxigen converters, 180-220 kg per ton of produced steel [3]. Water pollution depends on the part of the technological process. The most severe water pollution is the result of the contamination of waste water with rolling grease and friction oils.

Copper mines and Smelting Complex, Bor, is the only Serbian producer of copper and copper alloys. Waste gases generated during smelting are inputs for the production of sulfuric acid, employing a single contact catalysis process. During the production of copper and a simultaneous production of sulfuric acid, the efficiency of sulfur is between 4 and 62 %, with the emission of sulfur dioxide between 26 and 260 tons per year [4,5], Table 2.

Also, seven different wastewater sources exist from the mining activities, the tailing ponds, and the metallurgical activities. Almost 1285 t of iron, 502 t of copper, 1.5 t of nickel, 0.5 t of arsenic, 52 t of zinc, 2 t of lead, 300 kg of cadmium and 61 t of manganese are discharged annually into the rivers [5].

The production of primary aluminum is not present in Serbia. On the other hand, the production of aluminum alloys based on recycling shows considerable capacities, approx. 115000 t. The investments in these companies during last two years have made a significant improvement towards the cleaner production fulfilling all requirements. The other group of producers of Al alloys is small melting houses for end-of-life aluminum parts (automotive and household). Their capacity is not clear, but it is obvious that they work in a primitive manner, disposing solid waste (slag) and generating air pollutants.

Table 2. The relation between the quantities of the processed dry copper concentrate, the produced sulfuric acid, sulfur valorization and SO_2 emission in 1985-2006 period

Year	Dry concentrate t/year	Production of H_2SO_4 t/year	Valorization of sulfur %	Emission of SO_2	
				t/year	t/day (average)
1985	532000	318000	56	158000	430
1986	547000	310000	53	174000	480
1987	531000	251000	48	172000	470
1988	561000	303000	53	165000	450
1989	571000	324000	56	156000	430
1990	569000	346000	62	133000	365
1991	624000	296000	49	194000	530
1992	506000	211000	42	186000	510
1993	311000	56300	18	161000	440
1994	405000	153000	4	212000	580
1995	390000	64000	17	215406	590
1996	518342	169134	35	230466	631
1997	511 581	117900	24	259824	712
1998	485214	177303	38	203210	557
1999	292931	25798	9	176306	483
2000	256117	72894	28	120924	331
2001	188976	42727	22	96522	264
2002	214 831	65 689	30	98428	270
2003	100328	21968	21	51716	142
2004	90883	51338	53	26098	71
2005	177877	93734	53	55528	152
2006	211000	92215	43	79236	400

The mining and metallurgical production of lead has a very long tradition. Due to its high toxicity, modern trends are trying to eliminate the use of lead in all applications where it is possible. On the other hand, lead is necessary for the production of car batteries, cables, printing plates, bullets, *etc*. Apart from the biggest producer "Trepča", several new small companies related to recycling emerged on the market during the last few years. The largest capacity of approx. 10000 t of refined lead and lead antimony alloys for car batteries is in the smelter Zajaca, located at the former antimony mine and refinery. The total capacity of other small producers is close to 5000 t per year. The most important fact related to the lead production is the use of a very primitive technology and the absence of protection of the environment (lack of filters in furnaces, waste water, *etc*.) and employees. At the same time, further pollution is generated from non proper disposal of acid containing components.

The production of zinc and magnesium, together with the production in foundries (casting of iron, steel and non-ferrous alloys) or smithies and surface treatments, more or less generate the above mentioned pollutants.

SOLUTIONS TOWARDS SUSTAINABLE DEVELOPMENT

Metallurgical industry is called upon to address the demands of the sustainable development and demonstrate continuous long-term environmental improvements in order to secure its continued operation [6]. Today's strict regulations dealing with the environment protection were characterized by the lack of flexibility, which often resulted in distrust and confrontation between industry and environmental regulators. Environmental legislation generally referred to the industrial waste management including specific measures prescribed by regulators regardless of whether they represent the best solution in particular circumstances. This inflexibility was overcome by the 96/61/EC Directive concerning the integrated pollution prevention and control (IPPC Directive).

The purpose of IPPC Directive is to achieve the integrated prevention and control of pollution arising from highly polluting industrial activities (energy industries, production and processing of metals, mineral industry, chemical industry, waste management, *etc.*), leading to a high level of environment protection as a whole [7]. Fundamental to this approach is the general principle that operators should take all appropriate preventative measures against environmental pollution in practice through the application of best available techniques (BAT) under economically and technically viable conditions, in order to achieve a high general level of environment protection as a whole. Referring to metallurgy, following 6 (of total 32) best references documents are available: (i) iron and steel production [8], (ii) non-ferrous metals [9], (iii) ferrous metal processing [10], (iv) smithies and foundries [11] and (v) surface treatment of metals and plastics [12]. Also, it has to be pointed out that due to high toxicity the additional document referring to lead recycling is available in draft version [13].

In spite of the all obstacles, cleaner production can be introduced in a large number of companies. Necessary steps are mostly related to the management of the company, *i.e.* a firm decision to implement the principles must be made, to have continuous informing and education of the employees on the need and benefits of cleaner production, to make adequate business decisions and to insist on better energy efficiency [14-16], to input materials of higher quality, *etc.*

There are some good examples of the application of the cleaner production in metallurgical industry in Serbia. For example, Impol Seval - aluminum rolling company has increased the capacity together with fulfilling all requirements given present BREF for non-ferrous metals. The strongest improvements are obtained in the use of recycled Al and Al alloys, a slag treatment and off gasses minimization, Table 3. The slag treatment is based on the use of tarnish hot pressing device. The treatment of slags with alkali-chloride-fluoride rafination salts is eliminated. The increased use of Al containing scrap could lead to the larger emission of hazardous gasses generated during the melting of recycled cans (paint, coatings, *etc.*). In order to significantly decrease this emission, a regenerative and oxygen burners melting technology was installed. Also, the emission of Al is decreased approx. 25 %, together with the decrease of slag for approx. 30 %. Since this facility is operational for a relatively short period, more accurate data will be available in the period to come.

Table 3. Comparison of some process parameters for old and new foundry at Impol Seval

Parameter	Old foundry	New foundry
Capacity, t/year	50000	50000
Specific gas consumption, kWh/t	1560	800
Specific electrical energy consumption, kW h/t	41.4	60
Cooling water	17.3	16.6
Amount of recycled Al and Al alloys, %	2	30
Burn out of metal, %	2,43	<2.0
Slag, t/year	1398	<1000
Off-gasses	9356	3840

Figure 1 shows a new treatment of off-gasses generated during the ladle desulfurization of molten metal. Also, US Steel Serbia is in the process of modernization of two major gas filters in the steel works, which will minimize the emission of dust and gases, together with the system for the treatment of waste waters (this is the result of re-engineering of previous radial precipitators).

Figure 1. New facility for off gasses treatment in USS Serbia steel plant.

CONCLUSION

Due to the very important role of metallurgical industry in Serbian economy, a further development and market competitiveness have no alternative but to follow the principles of the cleaner production. Therefore, a new well-structured production model that should achieve a substantial prevention of waste generation and resources use optimization seems to be more urgent now than ever before. The road to the sustainable development will require modifications of activities concerning all three pillars: environmental protection – implementation of acceptable technologies; economic development – opening of new jobs and social cohesion – awareness that further development, leading to the devastation of the environment, is unacceptable in spite of possible profits.

REFERENCES

[1] Statistical Yearbook 2007, Institute of Statistic of Serbia, http://www.statserb.sr.gov.yu (1 October, 2008) (in Serbian)

[2] D. Vučurović, B. Nikolić, S. Ostojić, SIMS BUM, 1999, p.45 (in Serbian)

[3] LEAP of Municipality of Smederevo, Smederevo Municipality, 2006

[4] Ž. Kamberović, I. Ilić, M.Korać, Technological procedures for processing of tecnogenic row materials with copper at RTB Bor, Recycling agency, Belgrade, 2006, p. 87

[5] Ž. Kamberović, Assessment of utilized technologies and comparison with Best Available Technologies (BAT) Workshop: PREWARC, TMF-Serbia, Belgrade, 2007

[6] D. Panias, Consequences of Environmental Issues on Sustainability of Metal Industries in Europe: The Case Study of Bor, Report of the PREWARC Project, 2007, http://www.labmet.ntua.gr/intreat (1 October 2008)

[7] I. Giannopoulou, D. Panias, Act. Metall. Slov. **12** (2006) 105-110

[8] IPPC: Best Available Techniques Reference Document on the Production of Iron and Steel, European Comission, Brussels, 2001

[9] IPPC: Best Available Techniques Reference Document on the Production of Non-Ferrous Metals, European Commission, Brussels, 2001

[10] IPPC: Best Available Techniques Reference Document on the Ferrous Metals Processing Industry , European Commission, Brussels, 2001

[11] IPPC: Reference Document on Best Available Techniques in the Smitheries and Foundries Industry, European Commission, Brussels, 2004

[12] IPPC: Reference Document on Best Available Techniques for the Surface Treatment of Metals and Plastics, European Commission, Brussels, 2006

[13] Patrick Finlay, Draft Guidance on Best Available Techniques (BAT) for Secondary Lead Production, European Commission, Brussels, 2006

[14] Strategic Program of Energetic Efficiency in Industry in Serbia, Agency for Energetic Efficiency of Republic of Serbia, 2007

[15] Structure and Trends in Energy Consumption in Serbian Industry in period 1990-2002, Agency for Energetic Efficiency of Republic of Serbia, 2007

[16] E. H. M. Moorsa, K. F. Mulder, P. J. Vergragt, J. Cleaner Prod. **13** (2005) 657-668.