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RESEARCH ARTICLE

Cleaner production applications in various industries: metal industry

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ABSTRACT

In addition to many environmental issues, including climate change, the relationship between natural resource use and economic growth, and environmental impact and resource use must be reversed for the sustainable management of rapidly depleted natural resources. Cleaner production techniques enable a framework for identification, adaptation and harmonization for the best available technical (BAT) options in metal industry that aim at improving environmental discharges. Surface finishing, surface processing, surface covering, painting and similar processes are performed in the metal finishing industry. Although a wide variety of applications for the metal finishing industry covers cleaner production in Europe and in the world, these studies are limited in Turkey. In this study, it is aimed to evaluate the cooling liquid used in metal surface treatment and waste metal shavings, and to determine economical and ecological efficiency by determining the best available techniques and technologies. For this purpose, pH, conductivity NO^{-}_{2}-N, oil-grease analysis were carried out in SAMPA, a local metal processing company. According to the results of the analysis, the NO^{-}_{2}-N value increased until the end of the month over 10 mg L^{-1}, and the oil-grease and bacteria formation were also found to be quite high. All these analyzes and stages are determinants for the treatment and feed line to be established for the extension of the cooling liquid recovery and reuse and cleaner production practices will be determined.

Keywords: Best Available Techniques (BAT), cleaner production, metal industry

1. INTRODUCTION

Changes in our lifestyles and industrialization have led to an increase in the amount of waste in time and local environmental problems arising from these wastes have reached a global extent. Contrary to conventional pollution control approaches, cleaner production approaches aim to prevent / reduce pollution. Pollution control approaches adopt production and design phases as invariant factors and take pollution as an inevitable result of these steps and try to solve this problem once it emerges.

Approximately 99% of the enterprises in our country constitute Small and Medium Enterprises (SMEs) and their inability to complete their financial and technical infrastructure in general has always kept environmental investments backward. The solution to this problem is to enable industries to use more environmentally sensitive production techniques creating less waste, and at the same time increase their economic performance. Although cleaner production is based on "productivity" and brings permanent solutions to environmental problems, the difference between "pipe end treatment technologies" and cleaner production technologies is still not fully understood in our country. The number of countries adopting this approach is increasing day by day and cleaner production practices are started to be adopted and applied in every kind of production activities with the support of many institutions both at national and international scale [1].

The term "cleaner (sustainable) production" is defined by the United Nations Environment Program (UNEP) as a "holistic and preventive environmental strategy" the reduction of risks to people and the environment" [2]. The Integrated Pollution Prevention and Control Directive (IPPC-2008/1 / EC) issued by the European Union (EU) in 1996, covered legal regulations and supervisory authorities should allow industrial institutions within this general approach and administer environmental performance monitoring. In short, the IPPC directive provides an

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integrated approach to environmental air, water and soil conservation through the implementation of the "Best Available Techniques" (BAT), which is required to determine operating conditions and emission limit values for institutions to be granted.

1.1 Cleaner production and pollution prevention

Cleaner production relies on the principles of reducing the use of natural resources for unit production and reducing waste production by using high-yield production techniques. In other words, cleaner production should be understood not only to prevent environmental pollution, but also to increase productivity in economic terms. This approach consists of continuous and regular implementation of a preventive and integrated environmental strategy applied to production processes, products and services (Fig 1). As cleaner production is compatible with natural processes and the development of environmentally friendly new products, processes, systems and services, there is a close relationship with the concept of sustainability.

Fig 1. Cleaner production notion [3]

1.2 Tools and methods for cleaner production

Cleaner production practices are carried out in many stages of a product life cycle (raw material discovery, production, use and disposal after use). In this context, cleaner production practices require teamwork of many professions. Cleaner production tools include techniques regarding how cleaner production is to be implemented in the industry. These techniques can be explained in general under the following five headings.

- Waste Control
- Evaluation of Alternatives
- Chemical Evaluation
- Energy Assessment
- Environmentally Responsible Design

1.3 Benefits provided by cleaner production

Cleaner production can be applied to all small and large businesses, regardless of their level of material, energy and water consumption. Observations suggest that this approach offers an average resource reduction potential of 10-15% without making high cost investments. The possible benefits of integrating cleaner production approaches into production and management processes and resulting implementation are listed below [4].

- Integrated management strategy
- opportunity source
- harmonized strategy
- economic gains
- environmental benefits
- participation policy
- industry image and social benefits

1.4 Cleaner production practices in the World and Turkey

There are many studies in the literature about cleaner production especially in recent years. As can be seen from the studies listed below, the cleaner production approach is rapidly evolving to be new. Reduction in the use of raw materials and resources and in environmental impacts makes this approach important both for increasing the profitability of the companies and for ensuring the competitive advantage.

The studies on cleaner production work in the world and Turkey are given below.

Baral et al. [5] has achieved the result that chromium emissions can be reduced from 170 tons year^{-1} to 2 tons year^{-1} when fully compliant with EPA regulations, in a cleaner production operation electroplating industry in the United States.

Kupusovic et al. [6] in a cleaner production operation in a meat cutting plant in Bosnia, separate collection of animal blood, and spraying of the irrigation process; 32% reduction in BOD, 32% reduction in water use and 40% reduction in salt consumption, saving 669 Euros per year.

Fresner et al. [7] a study was carried out in a galvanizing plant in Austria to control the water and chemical inputs and outputs in production and to operate the factory with emission of "0". In this study, 50% reduction in water use and 40% reduction in acid consumption were achieved in the acid cleaning baths.

Environmental Program Support by Technology Development Foundation of Turkey (TDFT) in Turkey with environmental technologies (cleaner production/sustainable production) and their application projects undertaken by industry associations in the field of energy efficiency financing support is provided. In this context, practices that increase the environmental performance of the industrialist and reduce the production costs and thus increase the competitive power are supported. TDFT have done some studies in Turkey; Izmir Eco-efficiency (Cleaner Production) Program, UNIDO Eco-efficiency (Cleaner Production) Program, Industrial Symbiosis Project in Iskenderun Gulf, Bursa Eskişehir Bilecik Industrial Symbiosis Project, Trakya Industrial Symbiosis Project.

1.5 Best available technical (BAT) and documents

The Best Available Techniques (BAT) are defined as technologies that can be applied locally and economically, and the way they are applied, to provide the most effective protection of the environment as a whole. Reference documents (BREFs - Best Available Techniques Reference Document) have been created as part of the exchange of information under substance 13 of the Industrial Emissions Directive (IED, 2010/75/EU). The Existing Best Technicians (BAT) accepted under IPPC (2008/1/EC) and IED refer to the setting of permit conditions for facilities covered by the IED directives.

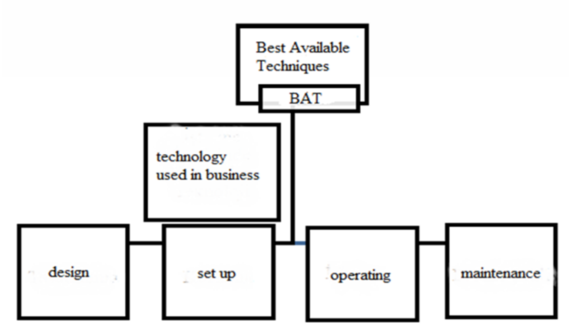

Fig 2. The Best Available Techniques (BAT) [8]

It should be emphasized that BATs do not only refer to the technology used within an enterprise, but also the way it is designed, installed, operated and maintained. (Fig 2). Some BATs are simple conclusions from common sense and do not require any investment. In practice, in order for a given technique to be considered as BAT, the following criteria must be considered:

1. If the technique is referred to as BAT in any BAT reference document (BREFs) then it is BAT.
2. If it is not referred to as a BAT in any BAT reference document (BREFs), it must be checked whether it is BAT, in accordance with the criteria contained in the Annex III list of the technical Integrated Environmental Requirements Directive (EC, 2006-a).

These criteria are:

- The use of technologies that cause low waste formation,
- Use of less hazardous materials,
- The necessity to prevent accidents and minimize the consequences for the environment,
- The general impact of the emissions on the environment and the need to prevent or minimize the risks,
- The time required to put the best available techniques into practice,
- The required period for the newly built or existing factory to run,
- Similar process, factory or business methods successfully tested on an industrial scale,
- The nature, effects and volume of the relevant emissions [8].

So, in this study, determination of pollution prevention and reduction activities in water and energy recovery, especially at metal industry, has been tried to be explained by determining the best methods for reducing and preventing the waste before it is generated by a continuous and preventive cleaner production approach.

2. MATERIALS AND METHODS

2.1 Study area- SAMPA industry

The company started to produce in Samsun in the 1950s, and in 1994, it was transformed into Sampa Automotive with its new structure. Sampa provides spare parts of heavy vehicles, tractors and trailers for the world automotive sector in Turkey, with its wide line of products ranging from motor for air suspension bellows to scissors, cabinet, stabilizer balance and bend arms, brakes, shafts, axles, V-arms.

With the use of precision metering, work is carried out by specialist molders in CNC Grinding Machines, multi CNC Cutting, CNC Turning, CNC Milling, vertical machining CNC Grinding Machines, all mold and machining metal parts requirement in 4000 square meters closed area mold and machining manufacturing unit (Fig 3).

Fig 3. SAMPA industrial machining unit with CNC workbenches

2.2 Method of production

In the Sampa industry, the cooling liquid used as input in the CNC machines for the metal surface treatment, and the waste metal shavings falling into the category of hazardous and toxic waste have been evaluated within the framework of the cleaner production approach and the best techniques and technologies that can be applied in this section have been determined and the economic and ecological efficiency has been studied.

In order to determine the characterization for recycling of the cooling liquid formed in this context, four CNC workbenches were applied to reflect the whole production. In addition, the technical and environmental performance of these chemicals has been examined using the cooling fluid provided by two different industries as cooling liquid. Within the scope of this data, two different liquids in the industry were used to monitor water samples continuously for four months using four different benches. In Table 1, TRC-17 and TRC-18 lathe machines, in which Ecocool cooling oil has been used, were coded as N1 and N2, TRC-19 and TRC-20 turning machines with Eurolub cooling oil were coded as N3 and N4.

Table 1. Coding of the cooling fluid used in CNC looms in the determination of waste characterization

Cod	Bench	Cooling Fluid
N1	TRC-17	ECOCOOL SNK-GTG
N2	TRC-18	ECOCOOL SNK-GTG
N3	TRC-19	Eurolub TE 290
N4	TRC-20	Eurolub TE 290

2.3 Waste characterization of CNC workbenches

A total of 112 composite samples of two different liquids taken from four CNC workbenches in the Sampa manufacturing industry were placed in a 500-ml sample vessel at the end of each shift, resulting in approximately 1500 mL of composite samples of each day for each workbench. The life of the cooling fluid varies between 2 and 6 months and is used continuously in the system every day. This process lasted for 28 working days and all 112 samples taken from the four counters were measured at the specified parameters. The waste characterization was determined by measuring the concentration of refrigerant oil, the pH value, the NO^-_2-N concentration, the conductivity, the oil/grease concentration, the waste metal shale oil/grease concentration (Table 2).

2.4 Laboratory works for cleaner production options

Phase separation (sedimentation), filtration and centrifugation tests were carried out for the separation of metal powders, especially suspended solids (SS) (mixed in the cooling liquid), from the BAT options specified as the cleaner production option. The amount of oil / grease was determined for removing oil / grease formation and the methods of stripping were investigated. Parameters and measurement methods to be examined in this context are given in the table below (Table 3).

Table 2. Measurement parameters and measurement methods for waste cooling fluid (input and output)

Parameter	Measurement Method	Mark/Model
Coolant oil concentration	Refractometer	Hanna Instruments/HI 96801
pH value	pH meter	C5XX Series Multi-Parameter
NO^-_2-N concentration	Nitrite analysis	T70 UV/VIS Spectrometer - 14776
Conductivity	Conductivity meter	C5XX Series Multi-Parameter
Oil / Grease	Extraction	-
Oil / Grease (Metal Saw)	SM-5520 D Soxhlet Extraction	Procurement of services

Table 3. Experimental parameters and measurement methods for re-use of cooling fluid

Parameter	Measurement Method	Mark/Model
Suspended solids and phase separation	Sedimentation	IMHOFF Cone Separator
Suspended solid amount	Filtration	Whatman Filter Paper: CAT No: 1441-125
Phase separation	Centrifugal	SED Centrifuge

3. RESULTS AND DISCUSSION

3.1 pH analysis result evaluation

The pH value should be about 9 in the cooling liquid (according to the industry values) (Annex C) and the Water Industry Pollution Control Regulation must be between 6-9 according to the metal industry receiving environment discharge standards (Water Pollution Control Regulation, 2004). It may be possible for the pH value in the cooling fluid to decrease due to reasons such as the concentration change, the presence of too many bacteria, and the use of cooling liquid in the system for a very long time. The reduction in the amount of pH indicates that the cooling liquid is contaminated and is no longer available to the system. As a result of the analysis results, the minimum pH value for N1 machine was 8.53, the maximum was 9.82, the average was 8.94, the minimum value for N2 machine was 8.55, the maximum was 9.92, the average was 8.96, the minimum value for N3 machine was 8.58, maximum 9.65, For N4 machine it was determined that minimum 8.5, maximum 9.73, average 8.94, and the results were observed at the limit value range (Fig 4).

3.2 Evaluation of conductivity analysis results

Conductivity should be 0-6000 µS cm^{-1} in the cooling fluid. If the conductivity is > 6000 µS cm^{-1}, this is an indicator of the presence of harmful substances, such as dissolved heavy metals, and if necessary, a coolant oil change is required. Following the analysis results made, the minimum amount of conductivity for N1 machine was 1.95, maximum 4.11, average 2.76, minimum 2.08 for N2 machine, average 2.73, for N3 machine, maximum 4.04, average 3.54, minimum 3.14, for machine N4, maximum 3.92 , minimum 3.14 with an average of 3.58. Fig 5 shows the change in conductivity values with respect to the dates.

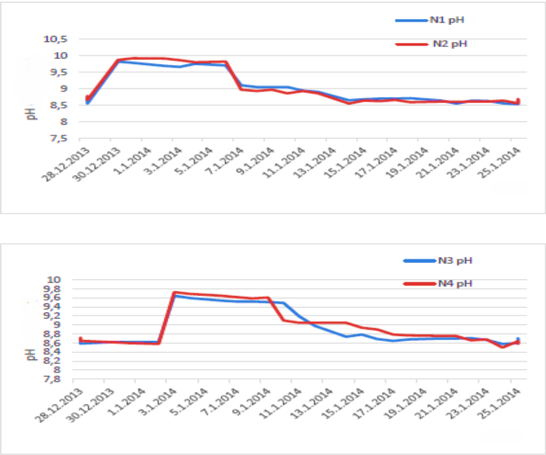

Fig 4. pH change for waste characterization

Fig 5. Conductivity change for waste characterization

3.3 Assessment of NO^{-}_{2}-N concentration results

The constant increase or increase in nitrite nitrogen concentration is indicative of bacterial growth with the formation of pollution in the cooling fluid. This result also shows that the quality of the cooling liquid deteriorates. At the end of the analysis results, the minimum NO^{-}_{2}-N concentration for the N1 machine was the minimum 3.83, the maximum was 9.33, the average was 5.46, the minimum for the N2 machine was 3.68, the maximum was 9.04, the average was 5.67, the minimum for the N3 machine was 3.17, the maximum was 10.4, the average was 5.94, the minimum for the N4 2.26, maximum 9.84, average 4.74. In order to be able to reuse the cooling fluid, nitrite nitrogen concentration should be within the range of 0-5 mg L^{-1} (Water Pollution Control Regulation, 2004), but this value is seen towards the end of one month and 10 mg L^{-1} for NO^{-}_{2}-N concentration (Fig 6). This reduces the service life of the cooling liquid.

Fig 6. Change of NO^{-}_{2}-N concentration change for waste characterization

3.4 Evaluation of oil/grease concentration results

Another important parameter is oil/grease. Results of the experiments show that cooling liquid is contaminated with oil/grease during metal working, which seem to be constantly increasing along with suspended solids with regard to the usage time of cooling liquid. Analysis results of oil/grease concentration were as follow; minimum 4.47, maximum 12.86, average 8.83 for N1 machine, minimum 3.01, maximum 15.34, average 9.43 for N2 machine, minimum 3.4, maximum 14.4, average 8.52 for N3 machine, minimum 2.78 , maximum 13.74, average 8.93 for N4 machine.

3.5 Evaluation of cooling concentration results

In order for the cooling fluid to be efficiently used in the system, the desired refrigerant concentration is in the range of 5-7%, which is a specific ratio for each operation. For the life, performance and more economical use of the cooling fluid, it is very important to measure the cooling oil concentration by certain periods. At the end of the analysis results, the minimum amount of refractometer for N1 machine was 3.74, maximum 6.46, average 5.38, minimum 4.93 for N2 machine, maximum 7.48, average 6.05 for N3 machine, maximum 6.37, average 5.51, for machine N4 minimum 4.16 , maximum 6.89 , with an average of 5.91, and the results were observed at the required range of values. As cooling oil and water were added to the system at certain intervals, there was no significant change in the refrigerant oil concentration.

Sedimentation, filtration and centrifugation experiments were carried out except for waste characterization in order to reduce the pollution load and reuse of two different cooling liquids (Eurolub and Castrol) used in metal surface treatment. For this study, the pH, conductivity, refractometer, NO2, oil / grease, suspended solids measurements were performed primarily to determine the waste characterization before application for two different cooling liquids, which were used in different periods in the process (Table 4). Since two different cooling fluids were taken from the samples that reached the dirtiest point, the results were observed over the limit values. It was observed that the concentration of NO^{-}_2-N and the oil/grease concentration (Limit value: 10 mg L^{-1}) were higher than the limit values. The results for SS are quite high for the water pollution control regulation 50 mg L^{-1} which is the limit value in discharge standards.

Sampa industry uses Eurolub and Castrol cooling oils. The processing times of the cooling liquids processed for different periods of time for the cleaner production operation planned for the four milling looms (FRC-06, FRC-17, FRC-07, FRC-15) in the machining unit are given in Table 5.

Both samples were subjected to sedimentation and the amount of suspended solids determined by sedimentation was determined. After sedimentation, filtration and centrifugation were carried out to determine the amount of dissolved SS (Table 6). Solid matter yields of 63% (FRC06) and 50% (FRC17) were obtained by sedimentation and filtration and 10% (FRC06) and 29% (FRC17) after centrifugation and filtration. As a result of these processes, removal of suspended solid marked 67% for the first cooling fluid (FRC-06) and 64% for the second cooling fluid (FRC-17).

As a result of these applications, two different cooling fluids (Eurolub, FRC-06-Castrol, FRC-17) were evaluated and when the efficiency of suspended solids removal was evaluated, they both showed very close results. As a result, in practice, precipitation and filtration have been determined to be the BAT option that yields the highest score of SS removal.

Table 4. Initial analysis results for a cleaner production run in the laboratory

Sample	FRC-06	FRC-17	EUROLUB	CASTROL
View	Cloudy green	Light yellow	Green	Light yellow
pH	8.43	8.6	8.87	8.50
NO^{-}_2- N (mg L^{-1})	12.77	14.50	1.29	0.80
Conductivity µS cm^{-1}	14.50	14.1 0	4.90	4.10
Oil/Grease (mg L^{-1})	9.86	10.72	2.32	3.95
Suspended solid (mg L^{-1})	2322	1757	432	174

Table 5. Processing times of cooling liquids evaluated in Cleaner Production operation

Sample No	Explanation
FRC-06	5 month processed Eurolub refrigerated liquid
FRC-17	4 months processed Castrol cooling liquid
FRC-07	1 week processed Eurolub refrigerated liquid
FRC-15	10 day processed Castrol cooling liquid
EUROLUB	Unprocessed cooling fluid
CASTROL	Unprocessed cooling fluid

Table 6. Applied BAT options resultant SS (mg L^{-1}) analysis values

Sample	FRC-06			FRC-17		
Applied analysis	Pre-operation	sedimentation + filtration	Centrifuge + filtration	Pre-operation	sedimentation + filtration	Centrifuge + Filtration
SS (mg L^{-1})	2322	849	762	1757	870	615

4. CONCLUSION

Preventing environmental pollution is much cheaper and more effective than environmental restoration or reinstatement efforts. Today's developing technologies are solved by the end-of-pipe approaches, while solutions such as prevention and reduction of the waste are important. Cleaner production practice, however, provides sustainable benefits to businesses with optimal use of energy, natural resources and raw materials.

The purpose of this study is to determine pollution prevention and reduction practices in water and energy recovery by determining the best methods to reduce and prevent waste before it is generated by a continuous and preventive cleaner production approach. In this context, cleaner production application options of Sampa Company are evaluated, a comprehensive laboratory work is done, and with this application, how these techniques can be applied to the industry has been determined.

As a result of the studies carried out and the information obtained from the industry, it has been determined that both cooling liquids reach a level that cannot be used again for a period of about 5 months. Within the framework of the cleaner production approach, the cooling liquids are fed back to the system and the recommended options for lengthening the lifespan with the treatment techniques have been identified. As a result of the cleaner production studies made, the stages determined under the cleaner production options to form the necessary feedback line for reusing the cooling liquid in the system are sedimentation, filtration, oil stripping, and membrane filtration. Suggested BAT options are based on the work and evaluations done in the Sampa, and it is specific to this company.

Cooling liquids are contaminated in a short time with particles worn from metal surfaces during the process, which leads to a loss in cooling fluid efficiency and metal surface quality. Expensive cutting tools are worn off soon and the cooling liquid needs to be replaced bringing undesirably high costs. Thus, filtration is essential. Due to its consistency, foreign oil pile up at the top of the cooling liquid, blocks the ventilation of lower parts and causes bacterial growth. This bacteria growth deranges the fragile cooling liquid balance and results in problems such as rust, contamination inside the machine, insufficient oiling (short cutting edge life and poor surface quality related to this) and foul odour. This leads to important economical loss for industries and environmental problems. Oil stripping is a simply effective solution to these problems. Oil is stripped and can also be used within the industry for other oiling processes. As a result of this implementation, an extension in the life of the cooling liquid and feedback to the system are achieved with the removal of suspended solids in cooling liquids, stripping off the oil and a decrease in bacteria level. Membrane filtration is also recommended as a BAT option to prevent bacteria growth. Membrane filtration may not be preferred because of flow rate problem. As there is a continuous feedback in the system, the amount of bacteria that will be in contact with air in the cooling liquid will reduce. Also, the reduction in the amount of the oil through stripping will help remove bacteria.

This stands to be a case study for similar industries in Turkey with its economic benefits and environmental performance indicator provided by good management practices and process changes that result in cleaner production in the relevant company. Rational changes that can be made on any industrial process increase the efficiency of the system, prevent rapid deterioration of the environmental quality and give the investor financial advantage and prestige.

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REFERENCES

[1]. G. Demirer, "Basic Principles of Pollution Prevention Approaches", *Environment and Engineer*, TMMOB, Vol. 25, pp. 13-20, 2003.

[2]. United Nations Environment Programme (UNEP), 1996. "Cleaner Production: A Training Resource Package", Paris: United Nations Publications.

[3]. https://www.slideshare.net/farhanahmad5249349/cleaner-production-techniques-32977890 (Visit date: 27 February 2018).

[4]. http://www.cprac.org/en/projects/sustainable-consumption-and-production (Visit date: 15 September 2013).

[5]. A. Baral and R.D. Engelken, "Choromium-based regulations and greening in metal finishing industries in the USA", *Environmental Science and Policy*, Vol. 5, pp. 121-133, 2002.

[6]. T. Kupusovic, S. Midzic, I. Silajdic, and J. Bjelevac, "Cleaner production measures in small-scale slaughter house ındustry a case study in Bosnia Herzegovina", *Journal of Cleaner Production*, Vol. 20, pp. 1-6, 2005.

[7]. J. Fresner, H. Schnitzer, G. Gwehenberger, M. Planasch, C. Brunner,K. Taferner, and J. Mair, "Practical experiences with the implementation of the consept of zero emissions in the suface treatment industry in Austria", *Journal of Cleaner Production*, Vol. 15, pp. 1228-1239, 2007.

[8]. European Commission, Joint Research Centre European IPPC Bureau (EIPPCB), 2006-a.