NEGATIVE ASPECTS OF THE CUTTING FLUID APPLICATION IN METAL-WORKING PROCESS FOR THE ENVIRONMENT AND WORKERS' HEALTH

Maria Ilisi Monteiro
CDT Centro de Desenvolvimento de Tecnologia e Recursos Humanos- Escola de Engenharia Industrial (EEI)-
Faculdade de Ciências Aplicadas (FACAP)- Avenida Barão do Rio Branco, 882- São José dos Campos/SP
maria.ilisi@cdt.br

Abstract: The aim of this work is to present a bibliographical revision of the negative aspects of the use of cutting fluids in metal-working process, in relation to the environment and operators' health. Nowadays in Brazil it circulates in the metal-working centers from 20 to 100 liters of oils cooled per minute. This means a great volume to be managed not to pollute the atmosphere and the workers' health. According to specific studies, the cutting fluids can be considered responsible by a great number of occupational diseases. The contact can be directly through the original fluid, fog, steams or by-products formed during the metal-working process. The committee of the Occupational Safety and Health Administration (OSHA) establishes the implementation of risk control strategies in the cutting operations, rough-hewing and abrasion of metals. The discard of the oily wastewater is one of the concerns of the companies that aim the environmental certification and besides these residues they can be characterized by the complex mineral composition of oils, vegetables, synthetic, fatty acids, emulsified, corrosion inhibitors and biocides, the normative requirements for the discard of wastewater in reception bodies are quite severe. In reference to the exposed, it can settle down the development of researches related to the use and discard of cutting fluid in the metal-working process. They can bring significant benefits for adverse environmental impacts and for controlling or even reducing the number of the occupational removals.
Key words: Environmental Impacts, Occupational Health, Cutting Fluids, Metal- working Process.

1. Introduction

In the last few years the demand for information concerning toxicity and biodegradability of the oils used in the metal working process has increased unconditionally (Battersby, 1999).

The industrial growth together with the increase of industrial waste generation has represented a challenge to be overcome and it constitutes one of the great problems related to the environment mainly for the industries that generate dangerous waste.

The environmental pollution caused by derivatives of petroleum, oil and grease is a worldwide problem and each passing year the amount of oily waste released by industries of various segments grows suddenly. Nowadays from 20 to 100 liters of coolant oil circulate per minute in metal-working centers (Kammermeier, 2000), it means a great volume to be managed so that it doesn't endanger the environment and the operator's health. the oil volume generated in the current production process put the metal working industry as one of the great responsible for these spills.

The world oil consumption is around 42 million ton/year and the consumption reaches 900 000 m^3 oil/year, Business Commitment for Recycling (CEMPRE, 1995).

The metal-working finish process industry generates effluents with high concentration of toxic and corrosive components, which cause serious danger to the aquatic life. Besides being toxic the effluents generated by the metal working industry are not biodegradable (Oliveira and Daniel, 1999). That's why the industries show difficulties regarding the treatment of these effluents. The current alternatives for using the neat lubricant oil refuse are basically rerefining or packing it in drums for disposal on the appropriate industrial landfills since the material incineration must be preceded by a demetalization to obey the legal norms of atmospheric emissions (CEMPRE, 1995).

The emulsions and solutions can be discarded at random neither in sewage collectors nor in natural reception bodies. There is a need to separate the oil from the water before the disposal (Runge and Duarte, 1989).

The necessity of knowing the adverse impacts caused by the use of cutting fluids in the transformation industry goes beyond the problems related to the environment. The occupational health is nowadays an extremely important issue in the industrial centers.

Teixeira *et al.* (1999) describes specific studies developed through the last few years and the cutting fluids can be considered responsible for a great number of diseases observed in the workers of metalwork industry the permanent contact of the operator with the cutting fluids during the work day cause them harmful effect them. It can be a direct contact through the cutting fluid itself, by the fog, steam or by-products formed during the working process. Even specks, chip adhesion, vaporization, contact with wash water and disposal of contaminated fluids can bring about negative effects to the operators' health.

Studies show that permanent contact with cutting fluids and their by-products may cause many kinds of skin diseases, some kinds of cancer and lung diseases (Bennett 1994,1995).

The growing worry about the environmental issues together with the necessity of following the law lead to a strong tendency of reformulation of the cutting fluid composition. The intention is to eliminate the toxic products from the cutting fluid formula or even check out the possibility of changing the conventional process for a more up-to-date process that offer improvement in terms of occupational and environmental quality, productivity and economy.

2. Bibliographical Revision

2.1. Main characteristics of cutting fluids

The globalization of economy, product quality standardization together with the growing conscience in relation to the environment leads the society, as a whole, to demand from the industries a feasible attitude in environmental terms. On the other hand, these industries find themselves obliged to process the natural resources in an adequate way as well as improve their manufacturing technology. This issue leads to metal-working process where the cutting fluids are used in the metal-finishing process (Garnier 1993).

The basic function of the cutting fluid is to introduce an improvement in the metal-working process so that it can decrease the friction between the tool and the work-piece (Benito *et al.*2002, Hu *et al.* 2002; Sokovic and Mijanovic, 2001; Ferraresi, 1997).

The first researcher to find out and measure the influence of the cutting fluid in the metal-working process was the American F. W. Taylor in 1894. At first, he used a great amount of water at the work-piece chip tool and soon after he used a water soda solution, or water and soap to avoid the piece and tool oxidation (Diniz *et al.* , 2000).

The intention at that time was to decrease the undesirable effect of high temperature, but it brought disadvantages like the oxidation of the tool-piece-machine set, besides lack of lubrication. At the moment the disadvantages were detected there was the need to find out new cutting fluids. They started the researches that brought about the most varied product combinations like fatty and mineral oil, synthetic solutions and water, besides achlorine, sulfur, sodium nitrite, phosphorus, amine based additives, each one with its specific application for each kind of operation (Ferraresi, 1977) .

There isn't a conciliation concerning the classification of cutting fluids. A rather conventional classification is the one in that the cutting fluids are divided in two classes: neat and soluble oil (Motta and Machado, 1995).

The neat cutting fluids are basically minerals and even animal and vegetal and they have extreme pressure additives in their composition . The soluble oils are subdivided in emulsion and solution and are formed by the addition of mineral oils with the characteristic of being soluble in water. It's possible to find antiweld, anticorrosion, antioxidation, extreme pressure additives, among others, in this solution (Gryta, *et al,* 2001; Song *et al*, 1998; Ferraresi, 1977).

The emulsion group is composed by mineral oil at the rate of 1:10 to 1:100 together with the emulsifiers agents that guarantee its miscibility in water. The emulsifiers are polar tensoactive that reduce the surface tension forming a relatively stable mononuclear film in the oil water interface. To avoid the water corrosive effect it's usual to add some additives like sodium nitrite and biocide agents to the emulsion to inhibit the development of bacteria and fungi that are harmful to human health (Motta e Machado, 1995).

The semi-synthetic fluids are also called microemulsion because they present an amount of mineral water that vary from 5 to 50% in their formulation and some other additives or chemical component like anticorrosives, biocides and humectant agents (Motta e Machado, 1995)

The synthetic fluids are representatives in the solutions and don't contain mineral oil in their composition; the formulation is based on chemical substances that form the solution in the water. They are the organic and inorganic salt, lubricity additives, biocides, corrosion inhibitors among others. (Portela *et al* 2001; Runge and Duarte, 1989; Ferraresi, 1977).

The table 1 presents the main group of additives and specifies the main composition, functions, action ways and environmental and occupational (Damage for the environment and human's health, 2002).

Table 1. Main additive groups (Damage to the environment and to the human's health, 2002)

	Function	Composition	Way of Action	Environmental and occupational inconveniences
Emulsifiers	Emulsion stability	Ionic Soaps, ethylene oxide sulphonate	Makes possible the micells formation	COD flown into hydric bodies
Corrosion inhibitors	Protection against the corrosion of the piece-tool	Long chains(-), nitrites, organic salts, amines, amides, boron components	Long chains attracted and retained by metals	Formation of nitrosamina and very toxic boron
Stabilizer, solubilizer, antifoam agents	Stabilize the concentrate and avoid foams	Alcohols, glucoses phosphates and silicones	Vary the surface tension	COD
Extreme pressure additives	Form intermediate covers, lubricating the cutting are	achlorinated paraffin, sulfur and phosphorus compounds	Use the temperature and pressure to react and form covers	Very toxic chlorinated products
Biocides	Prevent from the development of bacteria in cutting fluids	Isotialones, triazins, formils and phenolles	Bactericidal and bacteriostatic	Attack the microflora ecosystem and are quite toxic causing occupational dermatitis

2.1.1. The negative impacts to the environment due to the application of cutting fluids.

Due to the great demand for these products in the metal working process some adverse situations happen at a particular moment of its utilization and disposal. According to Motta e Machado (1995), some factors must be considered when choosing the cutting fluids so that the choice isn't made based only on its cost per liter. It's necessary to do a research about cost benefit that will justify the choice, such as:

1) number of tool sharpenings;
2) machine down time;
3) operator´s free time;
4) the fluid durability and what interests most in relation to the environment:

a) disposal facility;
b) recycling cost.

The negative impact caused to the environment due to the indiscriminate discard of lubricant oil in water bodies is quite violent. One ton of lubricant oil represents the equivalent of a pollutant load of 40,000 inhabitants and just 1 liter of lubricant oil is able to deplete the oxygen of 1 million liters of water (CEMPRE, 1995) .

The problem related to the disposal of these products in the water is the formation of a pellicle on the surface (the water is denser than the oil). It makes difficult the air and water passage that are indispensable for the breathing and photosynthesis of some organisms. The Brazilian Association of Technical Norms, through the Brazilian Regulating Norm 10.004 describes the lubricant oils as containing strong metals and highly toxic compounds, so they are classified as Class 1 Waste- Dangerous Waste (ABNT-NBR-10.004). There is an estimate that all over the world 42 million ton of lubricant oil are used yearly and 22 million ton of spent oil are generated and from those only 1million is rerefined or 4,5% (CEMPRE, 1995).

According to CEMPRE (1995) Brazil consumes yearly about 900.000 m^3 and generates 380.000 m^3 of spent oil. The remaining is usually burned or discarded directly in the nature. According Brazilian Association of Lubricant and Tribology (ABLT) it takes each liter of discarded lubricant oil from 100 to 120 years to deteriorate itself (ABLT, 2000).

According to Hersch (2001) the fabrication of metallic pieces produces a severe liquid that contains metallic contamination incluiding boron, chromo, iron, besides a variety of chemical compounds incluiding sulfuric acid, hydrochloric acid, potassium hydroxide, oils, synthetic fuids and surfactants.

On the metal working process pollutants coming from substances contained in oils and metals that are released in different ways: gases, steams and droplets of liquids constituting a particulate material or aerosols. The aerosols can be formed by a dispersion as a result of pulverization, atomization of liquids and solids and transfer of dust, pollen and bacteria to the suspension state due to the current of air. They're also formed by supersaturated steam or by reactions processed among gases producing a non volatile material and its main pollutants are (Macintyre, 1988):

a) Tobaccos solid particles, in general with diameters that are inferior to 10 u (micron), reaching even 1 u (1 micron = 0,001). They result of condensation of gaseous state particles, usually after the volatilization of fusin metal.

b) Dusts: the aerosols are formed in this case by solid particles usually bigger than the colloidal, with diameters between 1 u and 100 u and are result of mechanical desintegration of organic and inorganic substances be it by handling, trituration, sifting, working process, fusion etc.

c) Fume: they are aerosol formed by products that are result of incomplete combustion of organic materials (firewoods, combustible oil, coal etc)

d) Fog: They are constituted by droplets with diameters between 0,1 u and 100 u and are a result of steam condensation on certain nuclei or result of liquid mechanical dispersion as a consequence of pulverization operations, nebulization, specks among others.

e) Living organisms: the most common are the flower pollen (5 to 10 u), the fungus spores (1 to 10 u) and the bacteria (0,2 to 5 u until 20 u). In special circumstances and in general in confined places there may be the presence of virus (0,002 to 0,005 u).

In figure 1 it's presented scheme of waste emission to the environment through the cutting fluid action (Byrne, 1993).

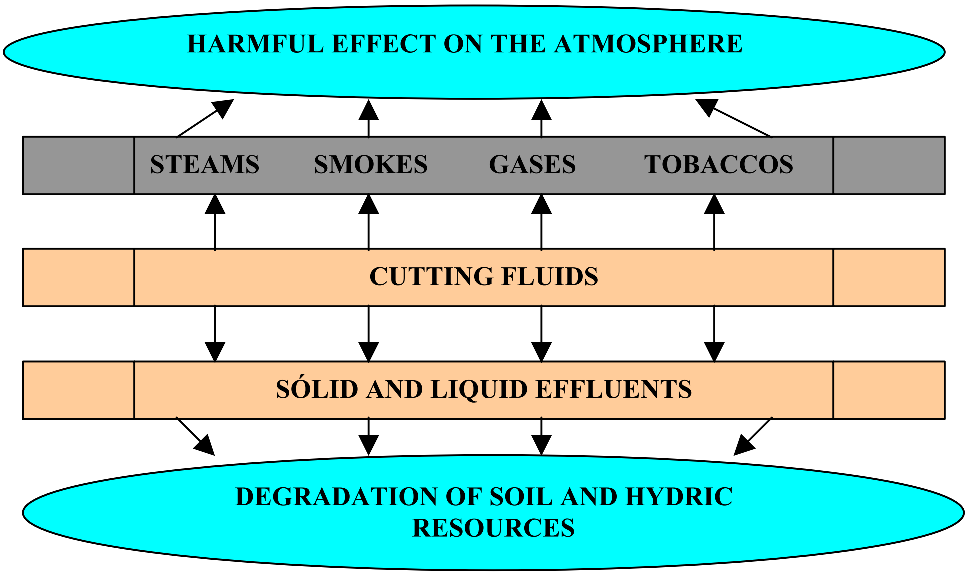

Figure 1. The harmful effects on the environment coming from emissions of cutting fluid wastes in the water, soil and on the atmosphere (Byrne, 1993).

El Baradie (1996) describes that the cutting fluids discard has been a constant issue at the enterprises and the supervision organs. The biggest problem of cutting fluids is related to the degradation and the final disposal of these products, some enterprises many times show a lot of inadequate practices, even for lack of information, like:

- inadequate handling;
- lack of a treatment plant;
- inadequate storage;
- inappropriate transportation;
- delivery in non authorized receptors;
- discard of waste in non-authorized places.

The concept of biodegradability can't be applied to the soluble cutting fluids (emulsions and solutions) (Scholz and Fuchs, 1999, Runge and Duarte, 1989). In a operating machine, the emulsion or the solution must last the for as long as it's possible. Therefore, a cutting fluid can not be biodegradable, on the contrary, the soluble cutting fluid has got to be biostable and compatible with the environment. It´s desirable that the water resulted of the emulsion discard won't have products that are aggressive to the fauna and flora. Phenoles and nitrite, largely used in the cutting fluids formulation, pass to the watery phase of the fluid and by the time of the discard they are found in the water as a result of the emulsion break, making the water improper the discard in reception bodies.

2.1.2. Cutting fluid use pertinent law.

Nowadays, one can count on specific law on cutting fluids. Through a review of the most recent texts of Brasilian Environmental Law, in that some resolution about the cutting fluid oil were found.

According to Brazilian Law Writings of 1996 (CLA), the decree 50.877 and its respective articles dispose about the toxic and oily waste in the interior and seaboard of the country. Among other articles the article 1 is about the discard conditions of the industrial liquid, solid, gaseous waste, which must occur only after being treated. This decree is also about the water quality patterns for industrial interests and determines that the monthly average of oxygen dissolved in water can't be inferior to four parts by million, neither the daily average inferior to three parts by million.

The monthly average of biochemical oxygen demand (BOD) can be neither superior to five parts by million of water (5 days/20ºC) and the pH won't be inferior to 5 neither superior to 9,5. Any pattern alteration will have to go through authorization of pertinent authorities (CLA, 1996).

According Resolution of National Council of Environment 020 (CONAMA) article 21, 6/18 of 1986 the disposal parameters of various chemical substances in water bodies, incluiding oil and greases must be respected because besides the man lubricant contact, the fluids cause negative effects when in contact with the environment (Brazil, CONAMA 20, 1986).

The CONAMA Resolution nº 9/93 says about spent lubricant oil considering that the Brazilian Association of Technical Norms (ABNT) in its NBR 10.004, Solid-Waste Classification. It classifies the spent oil as dangerous because it presents toxicity due to compounds like organic acids, potentially carcinogenic, polynuclear aromatic compounds, resin and lac.

In article 1 of the Resolution, the basic oil lubricant is understood as the main component of the lubricant oil that can be mineral (petroleum derivative) or synthetic (vegetal derivative or chemical synthesis) according to National Department of Fuel (DNC).

The article 2 of the CONAMA Resolution 9/93 describes that all the lubricant oils will obligatorily be taken and they will have an adequate destination, so that they won't affect the environment with adverse effects (Brazil, CONAMA 9, 1993).

In the article3 of the same Resolution it gets prohibited any discard of spent lubricant oils on soils, in superficial and/or underground water, territorian sea and sewage systems or evacuation of wastewater.

In the article 4 the industrialization and commercialization of new non recyclable lubricant oils, either national or imported, is prohibited Brazilian Institute of Environment and Renewable Resources (IBAMA) will have to evaluate the exceptions.

In the article 5 it gets prohibited the discard of waste that is product of spent or contamined oil in the environment without a previous treatment that will assure:

I- the elimination of toxic characteristics and pollutants of the air;
II- the conservation of natural resources;
III- follow the environmental quality patterns.

The article 6 establishes the creation of new industries applied for regeneration of spent or contamined lubricant oil as well as the enlargment of the ones that already exist must be based on technology that will minimize the generation of waste which is discarded on the air, in the water, soil or sewage system. In the same article in its sole paragraph the enterprises are required to give in to the competent environmental organ a scheme of their industrial processes that will assure the reduction and the generated waste.

In the article 7 it is estabilished that all the spent and contamined oil must be applied for recycling. The recycling must be done through rerefinment as referred in paragraph 1 and also the reutilization. Another industrial process will depend on the approval of the competent environmental organ as it is referred in paragraph 2 of the Resolution. In case it is not possible to recycle, the environmental organ may authorize its combustion for energy generation or incineration, since observed the pre-established conditions of article 3 that are:

- the combustion and incineration system, observing the article 250 of the decree-law 2848/40, must be dully licensed or authorized by qualified organ;
- the emission patterns estabilished in the environmental law in force. In case there isn't any pattern, the NBR 1266 (Incineration of Dangerous Solid Waste-Performance Pattern), and
- polychlorinated concentration (PCB's) obey the limits estabilished by the NBR 83.71.

2.1.3. The cutting fluids and the operator´s health.

Acccording to Koh *et al.* (2000) and Bennett (1994,1995) many researches show that the permanent contact with the cutting fluids and their by-products may cause many different kinds of skin diseases, some kinds of cancer and pulmonary diseases.

Macintyre (1988) describes that the pollutant agents of the environment are: gases, steams, dusts, tobbacco, fogs, microorganisms and odors. The pollution in large scale, according to the pollutant, can result in serious diseases. Among them some shoud be mentioned:

a) pulmonary emphysema;
b) high blood pressure;
c) liver diseases;
d) eye diseases and mucous irritation;
e) central nervous system diseases;
f) dermatitis;
g) skin cancer;
h) blood cancer (leukemia)
i) congenital anomaly (anencephaly: children who are born without brain, hydrocephalus is the increase of liquid in the encephalon and microcephaly is the reduction of the brain);
j) alteration in man's and woman's fertility.

The soluble cutting fluids emulsions are likely to an intense activity of microbiological deterioration. In normal conditions of operation the emulsion can be contamined by a complex biological population, these microorganisms can bring risks to the health due to the toxin production. The presence of pathogenic microorganisms like the gender ***Klebsiella, Staphylococcus, Shigella and Salmonella*** have been reported (Sulliman *et al.* 1997).

Skin diseases like dermatitis are caused by cutting fluid and soluble oil contact. The problem is related to the fluid and also the dust that obstructs the pore and the capillary follicle. The natural oiliness of the human skin and the bacteria that usually live on the skin accumulate on the human's epidermis that is already in contact with the cutting fluid specks on the same skin, this combination gives origin to pustulous eruptions or follicular dermatitis(Ferraresi, 1977).

Ferraresi (1977) describes that organic origin oils or petroleum oil take from the skin its natural fat, drying the skin and leading to possible cracks. At the moment the cracks it gets exposed to infectious. Additives like sulfur, chlorine and vegetal or animal soaps bring about strong skin irritations.

According to Ali (1994) about 80% of the occupational dermatitis produced by the chemical agents is irritative the presence of steam, gases and dust may be a predisponent factor to dermatitis appearance. The fact of not using adequate protection like masks, boots, gloves and overalls or the incorrect use of them may contribute to such affections.

Through the law article 6514/77, the following definitions are Consolidated in the Employment Laws (CLT) (Oliveira, 2001):

- the insalubrious activities and operations are the ones that by they're nature, conditions or methods of work expose the employers to the effects of health harmful agents, over the limits of tolerance fixed according to the nature and intensity of the agent and the time of exposition to the effects, according to Regulating Norm 15 (NR) (Insalubrious Activities and operations);
- elimination and neutralization on the limits of tolerance and using the EPI´s (Individual Protection Equipment) predicted by the NR 6 and EPC (Collective Protection Equipment).

According to Camargo (1999) the committee of Occupational Safety and Health Administration (OSHA) that studies the risks of cutting fluids exposition, determines a unanimous implementation strategy to reduce the risk in the working process, hewing, medical supervision and training.

The exposition limit that the committee recommends for an average of 8 hours of work is 0,4 mg/m^3 for the thoracic particulate mass (0,5 mg/m^3 for the total particulate mass). The scientific basis for the recommended exposition was the research about the appearance of asthmas and pulmonary function decrease.

In relation to the exposition limit on environment with cutting fluids, neither the present law nor the consensus norms establishes this limit (Camargo, 1999). Another recommendation of the committee is the development of environmental management systems containing these fluids to best protect worker. One efficient management system is the confinement integration, ventilation, fluid control and development of a medical supervision program.

3. Conclusions

The growing volume of the industrial effluent combined with the limited space for the waste disposal, operational cost of the treatment plants and also the environmental law progressive demands have provided the development of new technology for the waste water. Although there is a specific law about the waste disposal, rerefining or incineration, the worldwide waste discard criminal actions still can't be prevented.

Due to the oily fluid complexity there aren't available processes to operate in an isolated way or that can repair all the effluent physical-chemical or toxicological parameters.

It's necessary to optimize the environmental management procedures in small, medium and large enterprises because the disposal volume is the sum of all the industrial segments, in spite of the fact that the volume is not always visualized by the inspection.

The number of small companies that work with the occupational and environmental management system is growing and is potentially risky for the environment and operators' health. The inspection is damaged because the companies are often located in urban areas and their disposal are thrown at reception bodies with no previews treatment. Most of these places have the municipal sewage system as the receptor and the law is clear on that, as shown on the article 21 of CONAMA n 20/86 which mentions that the parameters of various chemical substance spilling in water bodies must be respected, including oils and greases, because aside from the man lubricant contact the fluids can bring about negative effects to the environment.

There is also a need to look for a way to evaluate the metal working process regarding the cutting fluids handling. Besides machine confinement measures, technology change, operators'commitment regarding operating machines, these operators' function have to be changed to minimize or eliminate problems like: hearing loss, contact dermatitis, rhinits and sinusitis, minimizing administration problems like constant and prolonged leaves or even removal.

4. Bibliografical References

ABLT**. Associação Brasileira de Tribologia**. Disponível em: www.boletimpetroquimico.com.br/artigo3/index.htm>acesso em:01/08/2000.

ABNT (Associação Brasileira de Normas Técnicas) NBR (Norma Brasileira) 10.004 (1987). **Resíduos Sólidos- Classificação**, set. 63 p.

ALI, S. A. (1994). **Doenças Ocupacionais Relacionadas com a Pele:** Definição e Prevenção Disponível em: <www.balaska.com.br/doenças.htm > acesso em 20/11/2001**.**

BATTERRSBY, N.S. (1999). **The Biodegradability and Microbial Toxicity Testing of Lubrificants - Some Recommendations.** Chemosphere (41), p. 1011-1027.

BENNETT, E. O. (1994.). **Dermatits in Machinists**: causes and solutions. Texas: Biotech Publ.

BENNETT, E. O. (1995). **Systemic Diseases in Machinists**. Texas: Biotech Publ.

BENITO, M.J.;RÍOS, G. ORTEA, E.; FERNÁNDEZ.E.; CAMBIELLA, A.; PAZOS, C. COCA, J. (2002). **Design and Construction of Modular Pilot Plant For The Treatment of Oil-Containing Wastewater**. Desalination 147. Oviedo, Spain. p. 5-10.

BRASIL. **Resolução CONAMA n. 20**, de 18 de junho de 1986. Estabelece a Classificação das Águas Doces, Salobras e Salinas para todo Território Brasileiro.

BRASIL. **Resolução CONAMA n. 009**, de 31 de agosto de 1993. Diário Oficial da União de 1 de setembro de 1993. Dispõe Sobre os Óleos Lubrificantes.

BYRNE, G.; SCHOLTA, E. Environmentally Clean Machining Processes: a strategic approach. **Annals of the CIRP**, vol. 42, 1993. New York, 1993. p. 471-474.

CAMARGO, O. F. (1999). **OSHA Faz Recomendações Para Usinagem de Metais.** Disponível em: <www.safetyguide.com.br/notícias/010600-3.htm> acesso em 17/07/2001.

CEMPRE (1995). **Manual de Gerenciamento Integrado, Lixo Municipal**. São Paulo: IPT, p. 3-124.

COLETÂNEA DE LEGISLAÇÃO AMBIENTAL (1996). Instituto Ambiental do Estado do Paraná. Curitiba.

DAMAGE FOR THE ENVIRONMENT AND HUMAN'S HEALTH(2002). Principais Grupos de Aditivos. Disponível em: http://www.cimm.com.br:8080/cgi-win/construt.cgi?resultado+915. Acesso em 13/03/2002.

DINIZ, A.E. *et al.* (2000). **Tecnologia da Usinagem dos Materiais**. 2. ed. Artliber, São Paulo 244 p.

EL BARADIE, M. A. (1996). Cutting Fluids: part I, Characterization. **Journal of Materials Processing Thechnology**, n. 56, p. 786-797.

FERRARESI, D. (1977). **Fundamentos da Usinagem dos Metais**. V. 1. São Paulo: Edgard Blücher, 751 p.

GANIER, M. (1993). **Reciclar, Eliminar e Valorizar Fluidos e Resíduos de Corte**. Trad. N. P. Lima. Revista Máquinas e Metais, dezembro, p. 26-29.

GRYTA, M., KARAKULSKI, K., MORAWSKI, W., (2001). **Purification of Oily Wastewater by Hybrid UF/MD**. Szczein-Poland.vol.35, n.15, p.3665-3669.

HERSCH, P. (Ed) (2001). **Tratamento de Efluente Líquido de uma Indústria Metal-Mecânica.** Disponível em: www.cimm.com.br: 8080/cgi-win/contrut.cgi?configuradorresultado+100. acesso em 31/03/2002.

HU, X.; MOLNAR, B, E.; VATAI, G. (2002). **Study of Ultrafiltration Behaviour of Emulsified Metal-Working Fluids.** Journal of Desalination 149. Budapest, Hungary. p.191-197.

KAMMERMEIER, B. *et al.* (2000). Furação Sem Refrigeração: Somente Razões Ecológicas. Trad. de M. B. Campos. **Revista Metal Mecânica**, abril/maio, p. 62-69.

KOH, D; LEOW, Y. H; GOH, C.L (2000). **Occupational Allergic Contact Dermatitis in Singapore.** Journal of the Science of the Total Environment. Singapore, Singapore. p. 97-101.

MACINTYRE, A. J. (1988). **Ventilação Industrial e Controle da Poluição**. Rio de Janeiro: Guanabara, 398 p.

MOTTA, M. F.; MACHADO, A. R. (1995). Fluidos de Corte: Tipos, Funções, Seleção, Métodos de Aplicação e Manutenção. **Revista Máquinas e Metais**, setembro, p. 44-56.

OLIVEIRA, A .(2001). **Consolidação das Leis do Trabalho Anotada e Legislação Complementar**. São Paulo: Atlas, p.78.

OLIVEIRA, C. A. A.; DANIEL, L. A. (2001). **Prevenção de Poluição pela Redução de Efluentes Líquidos Industriais na Fonte de Geração**. In: Congresso Brasileiro de Engenharia Sanitária e Ambiental. Rio de Janeiro. Disponível em: www.cimm.com.br: 8080/cgi-win/construt.cgi?configuradorresultado+220. acesso em 31/03/2002.

PORTELA, J.R; LÓPEZ, J.; NEBOT, E.; MRTÍNEZ DE LA OSSA, E. **Elimination of Cutting Oil wastes by Promoted Hydrothermal Oxidation.** Journal of Hazardous Materials. Puerto Real, Cádiz, Spain. p. 95-106.

RUNGE, P. R. F.; DUARTE, G. N. (1989). **Lubrificantes nas Indústrias**. São Paulo: Triboconcept, p. 71-172.

SOKOVIC, M.; MIJANOVIC, K. (2001). **Ecological Aspects of the Cutting Fluids an its Influence on Quantifiable Parameters of the Cutting Processes.** Journal of materials processing technology, Ljubljana, Slovenia. p .181-189.

SONG, Y, C; KIM, I.S; KOH, S.C. (1998). **Demulsification of Oily Wastewater Through a Synergistic Effect of Ozone and Salt.** v. 38, nº 4-5. Water Science Technology. Korea, Korea. p. 247-253

SULIMAN, S. M. A; ABUBAKR, M.I.;MIRGHANI, E.F. (1998). **Microbial Contamination of Cutting Fluids and Associated Hazards.** v . 30, nº 10. Tribology International. Manamah, Bahrain. p .753-757.

TEIXEIRA, C. R. *et al.* (1999). Aspectos ecológicos nos processos de usinagem. **Revista Metal-Mecânica**, junho/julho, p.68-76.