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Review

Treatment of spent metalworking fluids

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Abstract

Metalworking fluids (MWFs) are widely used for cooling and lubricating during the machining process. The worldwide annual usage is estimated to exceed 2×10^9 l and the waste could be more than ten times the usage, as the MWFs have to be diluted prior to use. For UK industry the disposal cost is estimated to be up to £16 million per year. Used MWFs cause high levels of contamination and rancid odours due to the presence of complex chemicals, biocides, etc., so that their treatment and final disposal must be handled carefully. Conventionally this has been done by combined physical and chemical methods but, with tightened legislation, these routes are no longer acceptable. Now, biological treatment is being increasingly adopted as it seems to offer an alternative with the potential for significant cost saving. However, there are significant difficulties in operating bioreactors, such as maintenance of the stability of the microbial communities present in activated sludge plants (ASP). In order to resolve these problems, four major areas need to be considered: (1) the composition of the spent MWF and its inherent biodegradability, (2) the recalcitrant compounds existing in waste MWFs and their impact on microbes, (3) the nature of the microbial consortia and means of optimising it, e.g, temperature and the practical design of the bioreactor and (4) the requirements for nutrient supplements and optimal control conditions. The potential importance of understanding the microbial community has been studied by the use of molecular biological techniques such as polymerase chain reaction (PCR), denaturing gradient gel electrophoresis (DGGE), fatty acid methyl ester (FAME) and fluorescent in situ hybridization (FISH). The application of attached biofilm bioreactors and thermophilic aerobic technology (TAT) has also been studied. This review describes recent advances in each of these areas.

Keywords: Metalworking fluids (MWFs); Biological; Wastewater; Treatment; Molecular techniques; Thermophilic

Contents

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1. Introduction

Metalworking fluids (MWFs) have been used in industry since ancient Egyptian times (BP, 1969), but their formulation and the study of their mechanism in use has only been investigated during the last two centuries. MWFs can be divided into two main types, oil based and water based. The oil-based MWFs can then be classified into two categories, namely straight oils and soluble oils, and the water-based MWFs can also be divided into two, synthetics and semi-synthetics (Wilbert, 1973; Foltz, 2002). The latter type of MWF is currently the main group used in engineering applications and has resulted in increased amounts of organic chemicals being present in the MWF wastewater. In fact, the complexity of the composition of waste MWF streams has created immense difficulties for the waste disposal companies which deal with this type of waste, according to relevant reports and personal conversations with several waste disposal providers (Sutton et al., 1985; Sutton and Mishra, 1994; Spoors, 2003). Therefore, this review paper attempts to compare many of the methods used in spent MWF treatment and to provide an insight into the key areas for future research.

Before considering the details of treatment methodology, a review of the latest legislation requirements is essential in order to understand the standards to be met. First of all, the European Union demands that MWF manufacturers and suppliers provide products that are both safe to use and ecologically acceptable during their production and use (BLF, 2003). Legislation regarding the regulation of MWFs relates not only to health and safety but also to environmental concerns. In the UK, health and safety matters are monitored by the Health and Safety Executive (HSE) and environmental issues are policed by the Environment Agency (EA). Particular attention has been paid by the environmental authorities to used MWF disposal. The European Union Water Directive (2000/60/EC) has also prioritised substances and identified actions to be taken in order to minimise the impact on the environment. Furthermore, the European Union Directive (2000/76/EC) has addressed the problem of waste from incineration and provided an even stricter framework aimed at reducing the negative effect on the environment. The key pollutants to be reduced are nitrogen oxides (NO_x), sulphur dioxide (SO_2), hydrogen chloride (HCl) and heavy metals. (European Union, 2000a, b). Consequently it limits the amount of spent MWFs being disposed off by means of incineration. In other words, an alternative and cost effective option has to be identified and applied. The tightening legislation relating to MWF disposal has forced all industries to review their effluent treatment processes or waste disposal options to meet the targets. In the USA, MWF users who generate 10–100 m^3 are required to treat their process discharge on site (Burke, 1991).

Faced with all the tightening regulation, there have been many discussions regarding used MWF treatment including chemical, physical and biological methods (Sutton et al., 1985; Viraraghavan and Mathavan, 1990; Kim et al., 1989, 1992a, b, 1994; Aki and Abraham, 1998; Portela et al., 2001; Ji et al., 2004). In the early 1990s, the dominant disposal methods were chemical and physical processes; e.g., adding chemicals (lime, alum, sodium aluminate, etc.) or polymers, and using ultrafiltration and evaporation (Burke, 1991). Few biological treatments were employed. Although MWF treatment plants have existed for a long time, many of them are not suitable to treat current spent MWFs because most of the treatment plants were designed to deal with oil-based MWFs. (Sutton et al., 1985; Kim et al., 1994). Modifications have been made to improve these plants, so that they can be used for biological treatment. Otherwise, plants using a type of hybrid process involving combinations of biological and physical processes are also in use (DTI, 1998; Thomas, 2001). Recently, genetic engineering has also been employed to specify certain species that can enhance overall treatment performance (Van der Gast et al., 2004a).

It seems that there are many treatment technologies relating to the disposal of spent MWFs, but there is relatively little known about the effects of different compositions on disposal methods, the need for supplement requirements in treatment, the comparative performance of different dominating microorganisms, etc. Therefore, the purpose of this review is to: (1) summarise the compositions of MWFs listed in the literature, (2) outline the variable microbial communities existing in both MWFs and in treatment systems, (3) describe possible safety, health and environmental impacts, (4) compare different types of reactors being used in treating spent MWFs and (5) list relevant advantages and disadvantages of each disposal method.

2. Development of treatment processes

MWFs are commonly used as coolants and lubricants in machining processes to increase productivity, prolong tool life, prevent corrosion, etc.; therefore there is a wide