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# Using Vegetable-Oil-Based Sustainable Metal Working Fluids to Promote Green Manufacturing

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## ABSTRACT

The ever-increasing awareness of the environmental and health hazards of petroleum and mineral-oil-based metalworking fluids (MWFs) is forcing the scientist and tribologists to develop alternative MWFs. Mineral and petroleum-oil based MWFs are also considered non-biodegradable which hinders their successful implementation in metal machining which requires regular disposal of used cutting fluids. On the other hand, vegetable-oil based MWFs are considered as sustainable green metalworking fluids/lubricants which are biodegradable and have superior cooling and lubricating properties. A review is done on current literature which shows that vegetable-oil based MWFs are not only better alternatives considering its eco-friendly nature but also offers better machining performance by enhancing the cutting tool lifetime and minimizing the cutting tool/workpiece interface temperature, friction and surface roughness. Different cutting methods like dry machining, flood cutting, and minimum quantity lubrication techniques are compared for a better understanding of the reported studies.

## KEYWORDS

Coolants, Dry Cutting, Environment, Green Machining, Lubricants, Metalworking Fluid, Microlubrication, Minimum Quantity Lubrication, Sustainable Manufacturing, Vegetable Oil

## INTRODUCTION

The metalworking fluids (MWFs) also known as coolants, cutting fluids or lubricants are mainly oils or any other liquids that are used in most of the machining operations to reduce the interfacial temperature of the work material and the cutting tool. The MWFs also help in reducing the friction generated between the machining zones by lubricating the contact area (Osama et al., 2017). The MWFs are also expected to increase the tool life, reduce the surface roughness, remove the chips from the machining area, and reduce the wear (Nune & Chaganti, 2019; E. A. Rahim and Sasahara, 2011; Siniawski and Bowman, 2009). MWFs are mainly obtained from the mineral based, petroleum based or vegetable-based fluid. Currently, the use of the MWFs has increase multifold because they offer many benefits. The European Union (EU) utilizes about 320,000 tonnes of MWFs/year. Out of this around 1/3$^{rd}$ is used and 2/3$^{rd}$ is required to be discarded. As of today, in the United States more than 1 million machining operators are made vulnerable to the exposure of machining lubricants (Vamsi et al, 2011) (Lawal et al., 2012). The global consumption of MWFs was 38 million metric tonnes and is estimated to increase by 1.2% over the next decade (Najiha et al., 2016). Due to this

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multifold increase of the use in lubricants there has been a noteworthy adverse biological effect on human health (Gupta et al., 2016).

Moreover, many recent and past studies have reported that the contact of lubricant with the human body is the major cause of respiratory and skin diseases. The effect can even escalate to a level where workers have been diagnosed with serious illness like organ failure and cancer (Krolczyk et al., 2019; Abdalla et al., 2007). In 2001, a study (Eisen et al., 2001) showed the drastic effect of lubricants on humans. It was reported that even at an exposure level of 1 $mg/m^3$ which is way less than the permissible limits, the effect on human body were as bad as smoking cigarettes for the entire year. One more study reported that an automobile company in France diagnosed chronic respiratory symptoms in more than 300 workers who were exposed to lubricant level which were half of the recommended value of 5.0 $mg/m^3$ (Huynh et al., 2009). Other than common skin diseases, other serious diseases like cancer is also associated with the consumption of petroleum and mineral oil-based lubricants (Xavior and Adithan, 2009) (Greaves et al., 1997).

The consumption of mineral oil-based lubricants are reducing with recently devised and introduced International Organization for Standardization (ISO) 14000 environmental series legislation (Singh and Gupta, 2006). However, all the used hazardous lubricants which is disposed-off is soaked by the ecological environment through various means making the entire ecosystem toxic (Cetin et al., 2011). Companies are trying to minimize the use of MWFs by implementing techniques like minimum quantity lubrication (MQL). Manufacturing industries are also looking for new types of MWFs to avoid recycling and disposal problems. Due to strict rules and regulation biodegradable lubricants like vegetable oil have gained popularity over petroleum and mineral oil-based lubricants. It is wiser to use such sustainable lubricants that do not cause any pollution (Pei et al., 2011). In the United States, it is expected that the biodegradable lubricants will grow at a yearly rate of 7-10% (Guzman Doris de, 2002). The molecular weight of vegetable oil in general is higher as compared to petroleum oil. The structure of vegetable oil is also polar by nature which gives them many important lubrication properties like lower volatility, higher flash point and viscosity and good boundary lubrication (Singh and Gupta, 2006). This polarity of vegetable oil and functional group containing oxygen gives its molecule the strength to adhere to the metallic surface and provide excellent lubrication (Woods, 2005). On the other hand, mineral oil-based lubricants, do not have any charge making them ineffective for lubrication (Panchal et al., 2017). Lubricants based on vegetable oils are available as straight oil or as water soluble products. They are free from chlorine which reduces their disposal cost. They even produce less concentration of mist. Vegetable oils are biodegradable, non-poisonous, can be used again and again, and are non-hazardous to the environment. All these advantages makes vegetable oil more likely to replace other synthetic lubricants (Gajrani et al., 2019; S. A. Lawal et al., 2012).

Figure 1 shows the Global Warming Potential (GWP) of different oils. GWP compares the global warming impacts of different sectors or gases with a standard value of carbon dioxide which is taken as 1 (US EPA, 2017). The figure shows that mineral-oil has around 45 times more adverse impact on global warming than $CO_2$. Some vegetable based MWF such as soybean oil resists oxidation and last longer in the sump (Stott, 2005). A potential MWF is called as 'Green MWF' if it has the following three aspects: safety, environmental impact and commercial sustainability (Hogan, 2010). Even though, vegetable-based MWFs have proven to be safe and eco-friendly their commercial sustainability strongly depends on their precise application and performance. The next section of this review covers research work conducted for different machining operations using vegetable based MWFs.

## TURNING USING VEGETABLE OIL-BASED LUBRICANTS

A research work (Katna et al., 2017) analyzed the effect of non-edible biodegradable vegetable oil-based metal working lubricants. A food grade emulsifier polysorbate was used in the MWFs. This emulsifier polysorbate is safe for humans; therefore, it is used as an agent in many food products. Experiments were conducted on a lathe using neem oil on EN8 material with uncoated carbide inserts.

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