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Transformer oil reclamation by combining several strategies enhanced by the use of four adsorbents

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L. Safiddine[1,2], Amel Hadj-Ziane Zafour[1], Issouf Fofana[3] ✉, Abdelhak Skender[1], Fettouma Guerbas[4], Ahmed Boucherit[1]

[1]*Laboratoire de Génie Chimique, Université Saad Dahlab Blida 1, Route de Soumaa, BP 270-09000, Blida, Algerie*
[2]*Chef Division, SKMK, Spa, Sonelgaz, Blida, Algerie*
[3]*ViAHT, University Québec, Chicoutimi, Canada*
[4]*LSEI Laboratory, USTHB University, BP 32 El Alia 16111, Bab Ezzouar, Alger, Algerie*
✉ *E-mail: issouf_fofana@uqac.ca*

Abstract: From an environmental perspective, petroleum-based aged oils removed from power transformers are source of several pollutants and therefore cannot be disposed of without due care. The degradation of oil in in-service transformers is due to various factors concurrent with the operation of the units over several years. The present study proposes a new strategy to rejuvenate used mineral oils by combining centrifugation, dehydration and sorption with four different adsorbents: activated carbon (ACH), silica gel (SG), magnesium oxide (MO) and activated bentonite (AB). The process of regeneration proposed in this study resulted in a level of restoration that saw the used oil take on the characteristics of new oil (colour, dissipation factor, resistivity, permittivity, acid number). The results also showed that the optimum form of the re-refined base oil can be attributed to a 10% (w/w) quaternary mixture of the adsorbents, itself comprised of 1% ACH, 6% SG, 1% MO and 2% AB. The anticipated benefits are reduced risk of dielectric breakdown blamed for over 75% of extra high-voltage (EHV) power transformer failures and extended transformer life expectancy by retarding the solid insulation aging processes.

1 Introduction

Insulating oils play an importance role in several industrial applications. Among a variety of uses are those concerned with power transformers with the aim of insuring reliability of these important assets. However, the drawback of the insulating liquid is that, under service conditions, it undergoes a slow but steady degradation processes. A progressive degradation and premature aging result from various phenomena including electrical and thermal stresses and chemical contaminants [1]. Moreover, metallic and cellulosic particles in suspension along with other products are impurities that increase the rate of degradation and shorten the useful life of the transformers. The failure potential of the transformer, therefore, is directly correlated with the liquid insulating material. Degraded insulating material is responsible for 75% of failed transformers [2].

The degradation of insulating oil begins as soon as the equipment is energised. A series of chemical reactions occur when the oil is exposed to a combination of electrical and thermal stresses, oxygen and the coil core components. Thus, as the oxidation process progresses, acids and polar compounds are formed and in turn become sludge. Sludge affects heat transfer between the core/coil and the tank/radiators surfaces. Consequently, the heat transfer capacity of the system is affected, increasing the operating temperature of the transformer and accelerating the degradation of the oil. Fortunately, mineral oils in this condition can be changed or treated by a specific process [3]. For good environmental and economic reasons, oxidised oils can be reused after regeneration. Regeneration means that unwanted pollutants are eliminated by adsorption processes, including the elimination of acidic components, water and other aging by-products. Currently, with adsorption as one of the principal mechanisms of regeneration, activated bauxite seems to be one key to resolve this problem. Activated bauxite is used as a low-cost adsorbent for the recovery of degraded oil and regenerates the oil to almost its initial condition. However, the drawback of the regeneration process with bauxite is the large volume of wastes. Thus, numerous investigations have attracted considerable attention by focusing on the production of low-cost adsorbents using cheap and available materials. As reported in various articles, the micro particles of carbonated of amorphous calcium phosphate (CACP) are an adequate adsorbent for the removal of polar compounds present in used mineral oil. Furthermore, as an alternative, biopolymers such as chitosan polysaccharide (CHS from natural sources—especially insects, crustaceous shells and fungal cell walls—are also used to bind the adsorbent CACP micro particles together, a high performance of the process compared with those where bauxite is used. Yet, activated carbon (AC) as conventional adsorbent has proved to be effective in this field and offers manifold advantages in terms of the removal of both organic and inorganic pollutants. This material has proved to possess great potential as adsorbent due to its porous structure and its high specific surface, which can be appropriately modified by physical and/or chemical treatments. The use of date pits, which constitute ∼10% (w/w) of the total weight of the date itself, has proved to be beneficial for this process. Moreover, using the date palm in this way offers a useful, substantial and beneficial alternative to simple disposal or use as animal feed [4]. Bentonite, occuring in natural form as clays, also hold commercial importance for bleaching oils and fats [5]. As such, they are termed bleaching clays. These particular properties can be modified for the purpose of colour removal (bleaching) and for enhancing critical properties. Usually, the mineral clays are treated with HCl and/or H_2SO_4 to reach activated forms. Relevant literature and extensive review papers describing the ability of activated bentonite's compounds in acting as an adsorbent for impurities, suspended matters, sediment and the removal of contaminants such as the ash and carbon content found in used transformer oil are available [6].

This article summarises work related to oil treatment of power transformers. The intent is to propose an environmentally friendly four absorbents-based system to rejuvenate service-aged oil. The objective of the proposed strategy is mainly focused on obtaining high-quality regenerated oil with properties close to new oil.