

## Investigating New Innovations to Detect Small Salt-Water Fraction Component in Mineral Oil and Small Oil Fraction Component in Salt-Water Projects

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**Abstract:** The main purpose of this study is to present the key findings on the effects of small salt-water fraction component,  $\beta$  expressed in volume % per L on rotation are presented in the temperature range of 19.0 to 24.0°C. It was found that rotations in oils with low boiling point known as light oils like Final diesel No. 2 were greater than the rotations which occurred in oils with high boiling point called heavy oils such as Esso diesel. Small oil fraction components,  $\gamma_s$  expressed in mL/L of salt water down to 10 ppm were detected. The greatest impact on rotation of these oils was found in light oils like Fina No. 2 diesel. At 40 ppm which is the oil content level below which the environment authority considers process water to be free from oil environmental hazards, the observed rotation angles were 23.2° for Esso, 36.7° for Nors Hydro AS, and 71.8° in Fina No. 2 diesel. It was observed that light oils molecules have drastic effect on optical properties of the mixture in which they exist. It was found that for all oils, oil fractions greater than 100 ppm, caused the medium to be optically dense. This technology has shown a very high potential of being used as an environmental monitor to detect oil fractions down to 10 ppm and the technique can use laser beam to control re-injected process water with oil fractions between 100-2000 ppm.

**Key words:** Digital display, environmental hazards, laser beam, laser power meter, mineral oil, salt water, small oil fraction component  $\gamma_s$ , small salt water fraction component  $\beta$

### INTRODUCTION

The different Regulation Authorities in the world require that process water exposed to the ocean must (Hammer, 2001) contain oil impurity concentration of less than 40 parts per million. Small fraction component of oils in water or water in oil (Thorn *et al.*, 1997) can be determined by PNA and NMR but not the rest. NMR and PNA are more complex and use expensive technology than any of the other methods. There is a need for a simple instrument (Hammer, 2001) that can be used to detect small fraction content of salt water in oil down to 1% or 10 parts in 1000 and oil fraction component in salt-water down to 40 parts in 1000 and oil fraction component in salt-water down to 40 parts in a million (40 ppm).

Mineral oils and salt-water are optically active liquids and since optical activity is one of the best methods of getting atomic structure information about transparent liquids, it can be utilized as an alternative method for detecting small fraction of salt water in oil,  $\beta$  or oil in salt water,  $\gamma$  (Herchet, 1987; Mucunguzi-Rugwebe, 2000).

The main objective of the study was to detect the composition of water in waters which contain mineral oils in salt water and oil. the purpose of this study was to

detect 1% salt water in mineral oils and 40 ppm of mineral oil in salt water so that this method can be recommended to be used as an environmental monitor to detect oil fractions to 10 ppm and also be applied in controlling re-injected processed water with oil fractions between 100-2000 ppm during oil extraction processes of getting oil from sea water (Mucunguzi-Rugwebe, 2000). The study aimed to disseminate the main results, of the hitherto known impacts of the small salt-water fraction component,  $\beta$  expressed in volume % per L on rotation are presented in the temperature range of 19.0 to 24.0°C (Mucunguzi-Rugwebe, 2000).

### METHODOLOGY

The study was recently done at the University of Bergen in Norway, was followed up with data update in December 2010, for data validation and relevance. Optical activity is caused by asymmetry of molecules that have spiral shape. It is an intrinsic property of molecular structure and is one of the best methods of obtaining structural information of a sample in which molecules are randomly oriented (Giancoli, 1989). The loosely bound electrons contribute most directly to optical activity. Since the molecules in a liquid rotated at random, the

rotation has an average effect on all the molecules throughout the liquid. One might at first, think that the random orientation of the molecules would cancel out the rotator effect entirely. But the molecules have a screw like arrangement of atoms and a right-handed screw is always right-handed no matter from which end it is viewed (Hetchet, 1987; Hudson and Nelson, 1990).

Due to asymmetry of molecules, the binding force on the electrons is not symmetrical. Electrons displaced from their equilibrium positions along one direction have a greater "spring constant" than when displaced along another direction. But propagation of electromagnetic waves through materials is a process of electrons absorbing and re-radiating this energy. Electrons respond to energy absorption differently along one direction unlike on another, prompting the waves to be transmitted with different speeds in different directions. These eigenwaves, for a given direction of propagation have well-defined phase velocities and directions of polarization (Yariv, 1987).

Linearly polarized light may be considered as the sum of two circular polarizations rotating in opposite directions. The electric field of a wave traveling through a medium polarizes the electrical charges of the atoms of the medium in the direction of the wave's oscillations. This polarization of the material is then in the direction of polarization of the wave. Due to the speed differentials, two circularly polarized waves which form a linearly polarized light, traverses optically active specimen, and they must be phased out. The resultant wave would appear to have rotated. When a given thickness of optically active materials is inserted between the analyzer and a polarizer, the condition of extinction no longer exists, because the E-vector of the light is rotated by the active medium. The optical rotation is (Thorn *et al.*, 1997) linearly dependent on the path length traversed by the light through the sample. The exact angle of rotation is measured by rotating the analyzer until the extinction occurs again. The rotation measurement depended on the: wave length of light, the thickness traversed by light, temperature, and concentration of the optically active substance in the solution (Pedrotti and Pedrotti, 1987; Kawamura, 1996).

This relationship is given by:

$$\alpha \text{ [degrees]} = L[m] \times \omega[\text{deg.m}^2/\text{kg}] \times d[\text{kg/m}^3] \quad (1)$$

where,  $\omega$  is the specific rotation and in liquids defined as the rotation due to a 0.1 m column length of the active liquid,  $\alpha$  is the net rotation, L, is the path length through which light traverses in the light and d is the concentration expressed as kilograms of active substance per cubic meter. There is a variation not only with solvents but also with concentration of the active substance. From experiment the rotatory power,  $\omega$  is

found to be adequately given by Jenkins and White (1976):

$$\omega = R + Sm + Tm^2 \quad (2)$$

where, R, S and T are constants and  $m$  is the amount of the active material in the solution. In case of mineral oil and salt water  $m$  is regarded as either the oil fraction component ( $\gamma$ ) or salt water fraction component ( $\beta$ ).

**Detection of small fraction component of salt water in oil,  $\beta$ , or oil in salt water,  $\gamma$ :** The experimental arrangement of detecting small salt-water fraction component,  $\beta$  in a litre of mineral oil and small oil fraction component,  $\gamma$ , in salt water was conducted. The experimental arrangement of detecting small salt-water fraction component,  $\beta$ , in a litre of mineral oil and small oil fraction component,  $\gamma$ , in salt water is shown in Fig. 1.

The continuous wave (cw) He-laser, L, model 1676 (1997) provided a randomly polarised light of 543.5 nm and produced light energy of 2.0 mW. A Polariser, P, was for improving the quality of polarisation of the beam; a green laser was preferred because:

- Green gives suitable rotation and higher penetration than red laser
- Economically cheaper than a blue laser

N is the sample container and C, a coil for producing static magnetic field. M is a mount with an orifice for detecting deviation in the beam's passage caused by misalignment of any item on the optical bench or brought about by refraction particularly when the sample was interposed between the Polariser and the Analyser, A.O is the orifice to assist in directing the beam to the detector head H; T is a tube intended to cut off ambient light (light from the surroundings) and is blackened inside to reduce reflection; D is the detector (laser power meter) model 45-540 (1998) and B is digital display multimeter for displaying the output.

The Analyser was rotated to obtain minimum irradiance,  $I_{\min}$ , when distilled water was in the container and angle,  $a$ , at which the minimum irradiance was noted (Mucunguzi-Rugwebe, 2000).

The value of,  $I_{\min}$ , was regarded as the irradiance reference in determining extinction point for all measurements. Since distilled or pure water is optically inactive, the angle,  $a_w$ , was given as the reference angle above or below which rotation was considered to have taken place. Accordingly, a litre of tap water was measured and mixed with 35 g of salt (Jozo) with the intention to get a salt-water of the same salinity degree as process water. Then first 1 L of Esso oil was mixed with the volume of salt-water equal to 1% of its (Esso oil) volume, that is, the volume of salt-water was made equal to 1% of the volume of Esso oil. The mixture was well

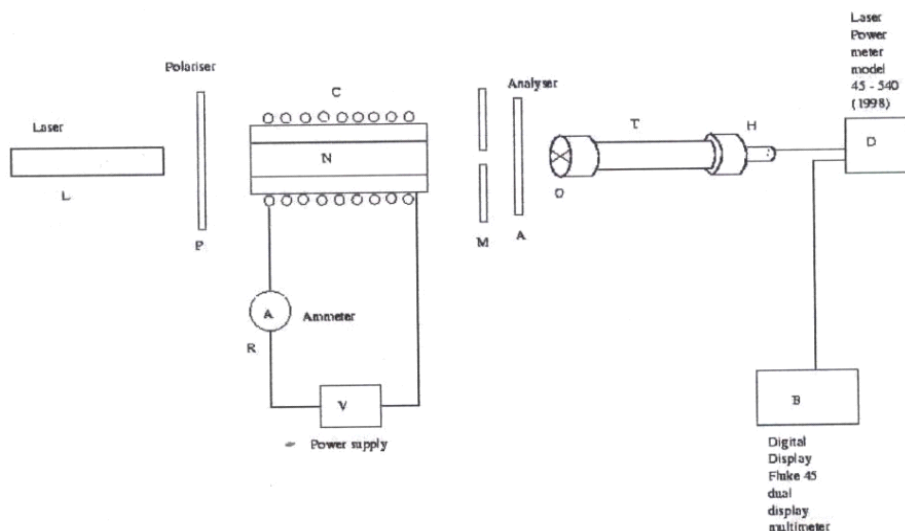


Fig. 1: Experimental setup for detecting small fractions of salt water in oil or oil in salt water

Table 1: The impact of % salt water in oil on rotation angle

Salt water fraction component	Rotation angle in degrees	Temperature (°C)
10% in Esso diesel fuel	35.1°	21.0
1% in Nors Hydro AS diesel fuel	74.5°	21.4
0.8% in Fina No.2 diesel fuel	301.0°	21.3

Table 2: Constants R, S and T due to % salt water in mineral oils

Salt water fraction component B in	R°	S°	T°
Esso diesel fuel	10.26	$-3.22 \times 10^{-1}$	$2.75 \times 10^{-1}$
Nors Hydro AS diesel fuel	10.80	-17.97	90.44
Fina no.2 diesel fuel	1.17	-15.78	489.53

stirred and some was poured into the sample container and the rotation,  $\alpha$  was measured. The same procedure was repeated for 2, 3, 4% up to 10% and the graph of rotation of the vibration plane against salt-water concentration in %/L of Esso oil, was plotted and the results were obtained. The experiment was repeated for light oils, oils with low boiling point like Nors hydro AS diesel and Fina diesel with reduced fractions of salt-water as salt-water changes drastically the optical properties of those light oils. A graph comparing the effect of salt water on rotation in each of the two oils mentioned above versus salt water fraction component was plotted and some results emerged.

The volume of 0.01 mL of oil was measured using a syringe graduated in millilitres and mixed with one litre of salt-water i.e. the volume of oil,  $\gamma$  was 10 parts in a million of the volume of salt-water. Because oil molecules quickly rise to settle on top of salt water, the container was rigorously shaken to ensure thorough mixing and the angle of rotation,  $\alpha$ , was immediately determined. The procedure was repeated with oil fraction component of 0.02, 0.03 up to 0.08. With the oil fraction component of 0.04 mL, ten values of the rotation angle were measured, an average was calculated and the S.D was determined for each of the three samples using equation:

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}} \quad (3)$$

where,  $x_i$  is the value of the  $i^{\text{th}}$  observable and  $\bar{x}$  is the mean value of  $n$  observables. A graph comparing the effect of three samples on rotation versus oil fraction component in mL/L of salt water was plotted and the results are shown in Fig. 4.

## RESULTS AND DISCUSSION

In Fig. 2, results of azimuth rotation against salt-water fraction component in % of Esso diesel lubricant per litre at 21.0°C are presented. The results obey Eq. (2) from which,  $R = 10.26^\circ$

The impact of salt-water fraction component in 1 L of Fina diesel No. 2 and Nors Hydro AS diesel on rotation angle of the vibration plane was compared and the results are shown in Fig. 3. A greater impact on the vibration plane is observed in Fina No. 2 diesel than in Nors Hydro AS diesel as shown in Table 1.

Finally in Fig. 4, three effects on rotation angle of the vibration plane due to fraction component in mL Fina

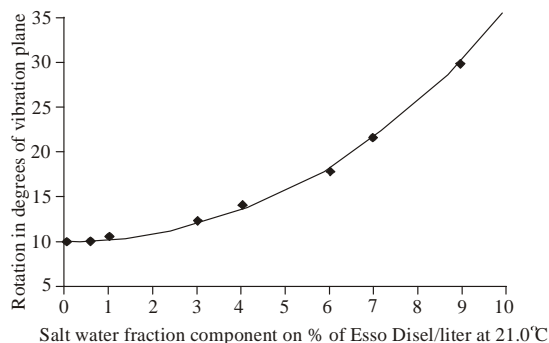


Fig. 2: Rotation of the vibration plane versus salt-water fraction component in % of Esso diesel/litre of Esso diesel at 21.0°C

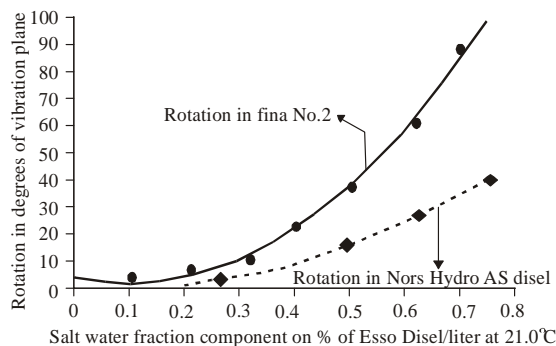


Fig. 3: Comparison between the vibration plane in salt-water component in % of Fina No. 2 and Nors Hydro AS diesel/L

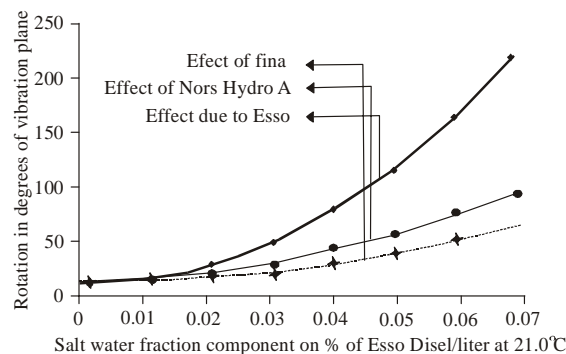


Fig. 4: A comparison of three effects on rotation of the vibration plane due Fina No.2, Nors Hydro AS and Esso diesel fraction components in ml/litre of salt-water at 21.3°C

produced highest effect, followed by Nors Hydro AS and the least effect was observed in Esso diesel as indicated in Table 2.

The constants R,S and T due to % in salt water in mineral oils are presented in Table 3. The rotation of the vibration plane in degrees due to oil fraction component of 40 ppm in salt water is presented in Table 4. The constants R, S, and T due to 40 ppm oil fraction in salt water are presented in Table 5.

Table 3: Effects of Esso, Nors Hydro AS diesel fuel and fina No. 2 fuel oil fraction on rotation

Oil fraction component in salt water	$\alpha$ in degrees	Temperature (°C)
0.0	8.3°	20.4
40 ppm of Esso Diesel	23.2°	21.3
40 ppm of Nors Hydro AS	36.7°	21.6
40 ppm of Fina Diesel No.2	71.8°	20.0

Table 4: Constants R, S and T due to oil fraction in salt water

Oil fraction in salt water	R in degrees	S in degrees	T in degrees
Esso diesel	8.20	33.34	$8.55 \times 10^3$
Nors Hydro AS diesel	8.36	166.00	$1.26 \times 10^4$
Fina no. 2 diesel	9.08	- 110.0	$4.10 \times 10^4$

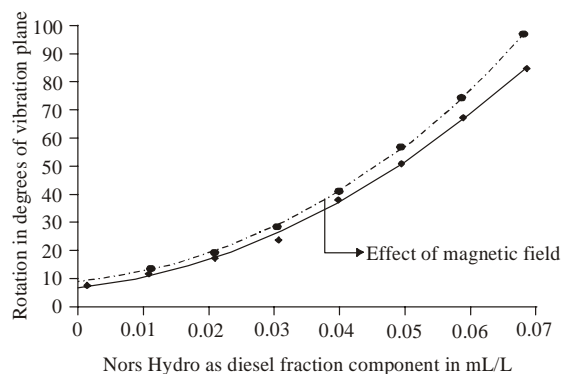


Fig. 5: Rotation of the vibration plane versus Nors Hydro AS diesel fraction component in mL/L of salt at 19.6°C with and without the applied static magnetic field

When static magnetic field was applied to one of the samples chosen at random, an increase in sensitivity was observed and the results are shown in Fig. 5.

### CONCLUSION

The method of optical rotation can be used to detect small salt-water fraction component in mineral oils e.g. fraction component such as 1% (1 part in 100) in Esso oil, 0.1% (1 part in 1000) in Nors Hydro AS diesel fuel and Fina No. 2 diesel fuel oil have been determined. Oil fraction components of  $\leq 40$  ppm in one litre of salt-water detected. At 40 ppm the rotation due to oil fraction component in salt-water was 23.2°, 36.7° for Esso, Nors Hydro As and Fina No. 2 diesel, respectively. Fraction component of light oil like Fina No. 2 diesel change drastically the optical properties of salt-water and therefore given higher rotations greater than those give by heavy diesel oils like Esso diesel. Finally this method can be utilised to design an instrument that can be used for: monitoring oil content in process water where it should not exceed 40 ppm according to the requirements of the environmental authorities, and controlling the re-injected process water in which oil fractions are between 100-2000 ppm.

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