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Forensic Science Analysis as an Emerging New Dimension of Environmental Issues

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Abstract

Forensic Science Laboratories deal with many cases under various acts including murder, accidents, poisoning, cheating, rape, paternity, illicit liquor, ballistics, cybercrime, and many more. The Environment Protection Act (E. P. Act) was enacted in 1986 with the objective of providing for the protection and improvement of the environment. There are specialized institutes that work on causes, consequences, and hazards of air, water, and soil pollution. The contribution of forensic science to the environment cannot be denied as the laboratory directly or indirectly analyzes different cases that can be linked with environmental issues. Cases are received under the 3,7 Essential Commodity Act (E.C. Act) to check the adulteration of fuel such as petrol and diesel with PDS kerosene.

Similarly, coal analysis in the cases of the exchange of low-grade coal with good-quality coal used in the power plant is also performed in the FSLs. Analysis of furnace oil for the detection of water and other metallic impurities is performed in FSLs. The adulteration of any fuel not only leads to loss of government revenues but also results in air, water, and soil pollution. In one of the cases, effluent from the steel industry thrown in nearby water bodies is also analyzed and the presence of pickling reagent was detected successfully. Such activities affect biotic as well as abiotic components of the ecosystem. In recent years, examination of nylon kite string (Manja) that falls in E. P. Act 1986 is also examined in FSL to ascertain whether the thread used in Manja is synthetic or cotton. Thus, the environment is one more aspect of Forensic Science that adds one dimension to this multidisciplinary field.

Keywords: Forensic chemical science; Environment; Fuel adulteration; Kite string; EP Act

Abbreviations: NGT: National Green Tribunal; EPA: Environment Protection Act; E.C. Act: Essential Commodity Act; CPCB: Central Pollution Control Board; IPC: Indian Penal Code; DMF: Dimethyl Formamide; HPTLC: High Performance Thin Layer Chromatography; PMCC: Pensky Martin Close Cup Elemental XRF (XGT)

Introduction

Science for justice is the aim of Forensic science laboratories. The main role of forensic science laboratories is to assist the judiciary system with the examination of physical, chemical, biological evidence. The examination reports generated by forensic experts help in punishment of criminals involved in many criminal cases. Besides the social cases, now criminal acts related to environmental issues are also considered. Hence keeping this point in mind, in India the National Green Tribunal (NGT) [1] has made different acts to control the activities harmful for the environment. Similarly, the Environment Protection Act (EPA) [2], enacted in 1986, is also involved in environmental issues. Air, water, and soil pollution are the major problems throughout the world.

To control these pollutions, sources of the pollution and their consequences must be studied to find out the solution. Various agencies are working on the same issues to make mother earth to be better placed not only for humans but also for all living creatures. Thus, as stated earlier, science for justice can also be applied to solving environmental issues to some extent. Different types of criminal cases received in laboratories of them few important cases related to environmental issues are discussed in the present paper. One of the major cases is fuel adulteration.

Kerosene is used as an adulterant in petrol and diesel. Blue dye is added to the kerosene and sold at a subsidized rate to distinguish it from industrial-used colorless kerosene [3]. Blue-colored kerosene is made available for the economically weaker class at a subsidized rate. This kerosene is used for illegal purposes such as adulteration of petrol and diesel.

The misuse of kerosene comes under 3, 7 Essential Commodity Act (E.C. Act) [4]. Hence various cases of petrol and diesel for adulteration with blue dye (PDS) kerosene are accepted and routinely analyzed in FSLs. Furnace oil is dark viscous oil used as oil for the generation of power or heat. Furnace oil is also used in many industries as fuel in furnaces/ boilers. Generally, adulteration of kerosene in furnace oil is very common, however sometimes water is also mixed with fuel oil. Hence such types of cases are also received in FSLs. Pickling is very important in the production of metal works. Strong acids are used in steel industries in Pickling process [5]. It is used to remove harmful impurities and to make the metal surface smooth and clean. The effluent generated after such treatment is harmful if discharged directly into the environment.

After acid treatment waste acid mainly contains metals such as iron, chromium, and nickel. After acid treatment wastewater becomes highly acidic and hence it must be treated according to local regulations to neutralize, and it should not discharge directly to the water bodies. The case in the same context was accepted and analyzed successfully in the laboratory. Use of synthetic kite string (manja) is one of these activities as it is harmful for human and bird's life. In recent years, there has been an increase in the number of cases in which both humans and birds have received fatal Manja injuries [6]. Hence cases of kite string/manja are received to detect the nature of manja. Thus, in addition to cases related to social justice, some important cases are analysed in FSL that are helpful in solving environmental issues to some extent.

Case studies

Adulteration Cases

Adulteration in petrol and diesel: The properties of kerosene are approximately higher than petrol but lower than diesel. Adulteration of diesel with kerosene leads to a decrease in values of density, IBP, FBP in the suspected sample, On the contrary increase in density, IBP, FBP parameters of the suspected petrol sample, confirms adulteration with kerosene. A detailed study in a forensic science laboratory on fuel adulteration is found very useful in detecting and confirming adulterants in fuel. Thus, reports generated by FSLs can be used to check the illegal activities that are the major cause of air pollution.

Furnace oil: Adulteration in furnace oil-thick brownish black colored viscous furnace oil is used in many industries as fuel in furnaces/ boilers. Analysis of furnace oil is a somewhat crucial job as it is a very dark, viscous, and sticky liquid. Adulterants make the furnace oil worse hence unsuitable as fuel in furnaces. The cases of furnace oil are also submitted to FSLs for analysis.

Acid

In one such case, effluent from the steel industry was discharged directly into nearby water bodies. The waste was so strong that plants near the water bodies were burnt and charred. The effluent filled in the tanker for discharging the waste and the waste found in the water bodies were seized and sent to the FSL for chemical examination.

Coal

Burning of coal as the fuel itself has an impact on air, water, and soil pollution. Use of poor-quality coal has no doubt lead to harsh effects on the environment. The case of the same concern has been analyzed in the laboratory. In a cheating case, a coal supplier got a tender to supply coal from a coal mine to a company. Three trucks loaded by the coal supplier were unloaded at the crime scene. Poor-quality coal samples were reloaded to three trucks and sent to the company. The company owner checked the quality of received coal and found cheating during transportation hence he lodged a complaint. Original coal samples from the mine and exchanged coal samples were submitted to the forensic science laboratory for comparison and the details of the exhibits received are as follows:

Ex-1- Coal sample from mine

Ex-2- Coal loaded from accused coal plot in Truck no.1

Ex-3- Coal loaded from accused coal plot in Truck no.2

Ex.4- Coal loaded from accused coal plot in Truck no.3

Ex-5-Coal from mine unloaded to accused site

Ex-6- Coal collected from Accused coal plot

Manja (Kite string)

Use of synthetic kite string (manja) is one of these activities as it is harmful for human and bird's life. In recent years, there has been an increase in the number of cases in which both humans and birds have received fatal Manja injuries. In India, therefore Central Pollution control Board (CPCB) [7] directed all state governments to prohibit the manufacturing, sale, storage, purchase, and use of all synthetic threads used for flying kites. Due to all those reasons kite string/manja is seized under Section 188, 336 of Indian penal Code (IPC) and 5,15 EPA and submitted to the forensic science laboratories for chemical examination.

Experimental

Analysis of Petroleum hydrocarbons:

The properties of petrol, kerosene, and diesel such as colour, density, distillation range were determined using standard analytical methods laid down by Indian standard specifications [3].

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- Density- Density of the sample was found using hydrometer and as measured by viscometer.

- Distillation range- Distillation range was analyzed using Auto Dist. Distillation Analyzer.

- Colour/Dye identification- High Performance Thin Layer Chromatography (HPTLC) technique was adapted to ascertain the presence of dye. Petrol samples, kerosene sample and adulterated samples were extracted in solvent N-N Dimethyl Formamide (DMF) and were spotted on TLC Silica Gel (60F 254) plate. The plate was developed in Hexane: toluene: Acetic acid 50:50:2 solvent system (after the chamber is well saturated with solvent system). The plate was developed to 10 cm. Then spots were observed visually as well as under UV chamber.

- Filter paper test- A drop of pure petrol and kerosene adulterated petrol samples were taken on filter paper and tested for purity. Petrol is a clean and highly volatile fuel and hence a drop of petrol vaporizes more easily and quickly from the filter paper without leaving any traces or patch of oil behind.

- The viscosity of sample was determined by Anton Paar viscometer SVM 3001.

- The flash point of the samples was determined by Pensky Martin close cup apparatus PMCC Flash Point tester Autoflash 93.

Analysis of Furnace oil

The density of furnace oil was determined by density bottle, and the flash point was performed using Pensky martin close cup apparatus. Wet tests were performed for detection of iron and aluminum.

Analysis of Coal samples

Coal analysis was performed as per standard procedure [8]. For moisture determination Hexatech oven was used. Ash content in the coal samples was determined by Using Muffle furnace. Horiba micro XRF XGT 7200 is used for element detection and to compare the spectrochemical composition of coal samples. Elemental XRF (XGT) point analysis was performed at conditions: - XGT diameter: 1.2 mm; X ray tube voltage: 50 KV; X-ray filter: None; Current: 1 mA. The analysis was performed for 100 seconds under a partial vacuum.

Determination of strength of seized acid

Preliminary examination of the seized samples shows acidic pH and confirmed the presence of chloride ions in the sample. The strength of acid was determined using Acid base titration. Standardization of sodium hydroxide (NaOH) solution was done with standard oxalic acid (0.1N) using phenolphthalein indicator and then this standardized NaOH solution was used for determination of strength of seized HCl acid. The elemental composition of precipitate found during titration is analyzed by Horiba micro XRF XGT 7200.

Thermal analysis of Manja

The STA was performed for detection of fiber type using NETZSCH STA 449. Aluminum crucible with pierce lid and nitrogen as purged gas at a flow rate of 40 ml/min and about 3-5 mg. Sample was used in this study were heated in the range of 20^0-600^0 at the rate of 20K/min. Data were analyzed using NETZSCH STA 449 Protease software.

Results and Discussion

Detection of kerosene in diesel and petrol:

The blue-colored kerosene is decolorized by various means such as filtering through charcoal, adsorption on fuller's earth or by addition of strong sulphuric acid and this decolorized kerosene is used for adulteration of petrol and diesel. Detection of kerosene in diesel and petrol was studied by using different techniques such as viscosity, distillation range, aniline point and chromatographic techniques etc [9-15]. The aim of the detection of adulterants is to assist the judiciary system through detailed reports regarding adulteration. The consequences of fuel adulteration are well explained in literature [16]. Thus, forensic analysis indirectly assists to check the misuse of subsidized kerosene that leads to air pollution. The Density of kerosene is approximately higher than petrol but lower than diesel as given in Table 1. Adulteration of diesel with kerosene leads to a decrease in values of density, IBP, FBP in the suspected sample, On the contrary increase in density, IBP, FBP parameters of the suspected petrol sample, confirms adulteration with kerosene (Table 1).

Detection of kerosene in furnace oil:

To increase the quantity of furnace oil kerosene is generally added as an adulterant. The density of kerosene adulterated furnace oil is slightly lower and less viscous than standard furnace oil and has a kerosene-like smell. The distillation of the sample gives a clear picture about the kerosene adulteration as the kerosene fraction in oil distilled out in the range of 112°C to 264°C. The results indicated that the sample received as furnace oil was adulterated with kerosene.

Detection of water in furnace oil:

During the transportation of furnace oil, the driver of the tanker sold about 450 kg of oil and mixed it with water. Then the tanker reached the company. Upon receiving the samples by the company owner, the furnace oil was tested, and it was found to contain excess water. The company owner lodged a complaint, and the samples are submitted to FSL for examination. Prima facia no separate water layer is observed as samples are dark viscous colored. The density of received furnace oil was found to

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be 1.0211 and the sample was unable to give a flash test. When the sample was taken for distillation, it distilled out at 101°C up to about 20-25% distillation, and the viscous oil began to distill out. The distillate in the range of 100-102°C was tested and found to contain water in the exhibit. The results are presented in (Table 2).

Table 1: Comparison of Properties of Petrol Diesel and Kerosene.

Property	Petrol	Diesel	Kerosene
(Colour)	Orange dye (Phenyl azo 2-naphthol)	Yellow	Colourless (Regular Blue dyed (Di-alkyl amino anthra-quinone) Kerosene for Public Distribution Supply) {PDS}
Flash Point	<-21°C	35°C to 40°C	37°C to 65°C
Density at 150C	710-770kg/m^3	820 –870 kg/m^3	0.78 – 0.82 g/cm^3
Boiling Point	25 to 75°C	250 to 350°C	190 to 250°C
Thin Layer Chromatographic Solvent System (Hexane: Toluene: Acetic Acid [50: 50: 2])	Pink or Orange colour Rf Value 0.49 & 0.51	Violet (Under UV lamp at 366nm)	Blue colour spot at Rf around 0.4

Table 2: Observation found during analysis of furnace oil.

Exhibit	Density at 250C	Flash Point	Water content
1	1.0211g/cm^3	Cannot determined	33.66%
2	0.9675 g/cm^3	86°C	7.50%
Reference Furnace oil	0.9576 g/cm^3	88°C	1%

Acid

The preliminary wet chemical analysis of greenish yellowish colored samples seized revealed, presence of strong hydrochloric acid in the sample. Acid base titration of samples with standard sodium hydroxide using phenolphthalein indicator confirmed the strength of seized acid in the range of about 18-22%. During titration, dark, orange-colored precipitate was obtained. This precipitate was dried and analyzed on micro XRF. Chloride, iron are detected by micro x XRF as shown in Figure 1 confirming the presence of a pickling agent (Mixture of concentrated Hydrochloric acid and ferrous ions) used in the steel industry for removing harmful impurities thrown in water bodies (Figure 1).

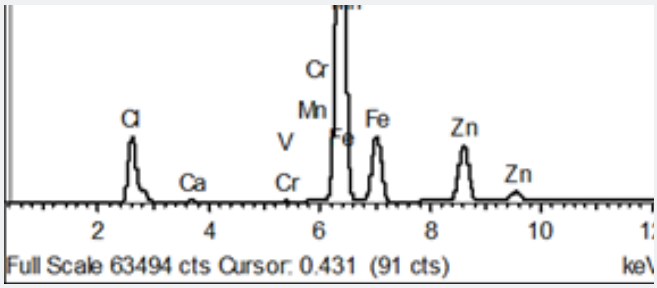

Figure 1: Elemental Analysis of Precipitate Found in Exhibit.

Coal

The results of chemical analysis of coal samples received from mine and exchanged poor quality coal samples were compared in the laboratory. Detailed data related to this study has been published earlier [17]. The properties of coal show remarkable differences in moisture content and ash content. The proximate analysis of coal samples is in good agreement with results obtained by advanced elemental detection techniques such as micro XRF. The results of the analysis are presented in (Table 3).

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Table 3: Comparative Results of Analysis of Coal Samples Received.

Parameters	Exhibit 1	Exhibit 2	Exhibit 3	Exhibit 4	Exhibit 5	Exhibit 6
Appearance	Black co-loured hard lumps	Black- and brown-coloured brittle lumps	Black- and brown-coloured brittle lumps	Black- and brown-coloured brittle lumps	Black co-loured hard lumps	Black- and brown-co-loured brittle lumps
pH	7 to 7.2	7 to 7.8	7 to 7.8	7 to 7.8	7 to 7.2	7 to 7.8
carbonate ions	Negative	++	++	++	Negative	++
Effect of dil. HCl	No coloration	Yellowish Greenish coloration	Yellowish Greenish coloration	Yellowish Greenish coloration	No coloration	Yellowish Greenish color-ation
Fe	+	+++	+++	+++	+	+++
Moisture (%)	9	12	14	12	9	15
Ash (%)	23.5	62.7	68.6	68	16.32	66.5
Colour of ash	Off white to pinkish	Brick red	Brick red	Brick red	Off white to pinkish	Brick red
Mineral matter	25.85	69	75.5	75	18	73.15
Specific gravity	1.48	1.9	1.93	1.93	1.41	1.91

Kite string: Analysis of Manja (kite string)

The examination of polymer can be done using instrumentation techniques such as simultaneous thermal analysis [18]. The analysis gives a clear idea whether polymer or cotton-based thread has been used in making manja. In thermal analysis cotton fiber (cellulose) shows an onset at 329°C while Synthetic fibers such as polyester show TG onset at 433.1°C and for nylon about 434°C -444°C. Melting peak for cellulose based cotton fiber shows broad endothermic peak in the range of 95-110°C. Synthetic fibers such as polyester show an endothermic peak at 249°C and nylon fiber show 221.5°C and 158.8°C respectively. Decomposition peak for cotton observed at about 360°C. Synthetic fiber shows decomposition peak at 455.8°C for polyester and at 464°C - 468°C for nylon fibers. Variation in onset temperature and DSC temperature for different fibers is presented in (Table 4), (Figure 2).

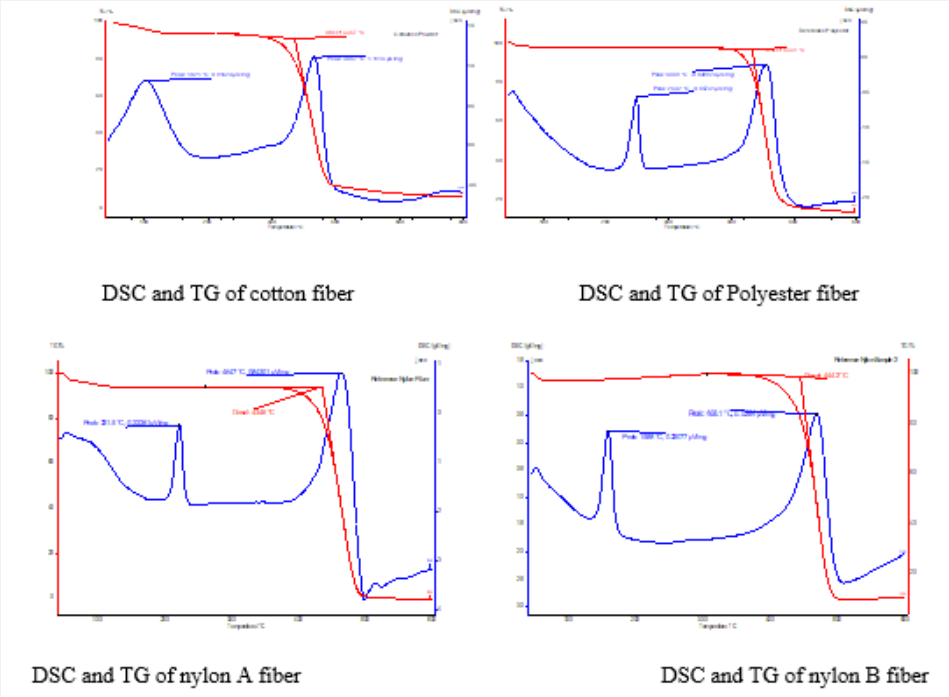

Figure 2: TG And DSC Pattern of Cotton and Synthetic Fibers.

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Table 4: Variation in Onset Temperature in TG And DSC Temperature for Different Fibers.

Sr. No.	Reference Fibers	TG onset Temperature (°C)	DSC Melting Temperature (°C)	DSC Degradation Temperature (°C)
1	Cotton fiber	329	104.5	357
2	Polyester	433.1	249.2	455.8
3	Nylon Thread 1	434.6	221.5	464.7
4	Nylon Thread 2	444.2	158.8	468.1

Conclusion

Presently there are different specialized branches of forensic science such as Forensic serology, Forensic DNA, Forensic Physics, Forensic chemistry; ballistics, cyber; speech and tape authentication and psychology engaged in solving different criminal cases. There is no specific environmental forensics branch that exists in Forensic science laboratories still State of the art forensic laboratories are at the forefront now in successfully solving environmental issues.

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