

# FORMULATION AND TESTING OF CLEANING LIQUIDS FOR SMALL FIREARMS

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**Abstract:** The aim of this study was to assess postural risks associated with the current gun barrel cleaning methods and to develop an ergonomic gun barrel cleaning liquid that could reduce such risks posed by conventional acidic and alkaline cleaners. Four such different formulations were tried namely, formulation-1, formulation-2, formulation-3 and formulation-4. The four formulations prepared and successfully tested by prescribed methods. Test results have shown that all four formulations were effective in cleaning the gun barrels and other parts of the gun. However, formulations 2 and 4 were found to be most effective in their intended jobs. Carbon removal tests and after-rust test also have been carried out successfully.

**Index Terms - Formulation, Gun cleaning liquid, patch test, carbon removal test, after-rust test.**

## I. INTRODUCTION

There are revolutionary changes in cleaning technology of firearms. Irrespective of the type of a gun, gun barrels require maintenance job of having to remove the powder residue after firing. There is a harsh environment of extreme heat, high-speed movement of parts, function, and rust, inside a gun, place big demands on cleaner and protect products [1]. Whosoever owns a gun, also needs a suitable cleaning liquid to keep its performance up to the mark always [2]. A suitable cleaning liquid is required to remove carbon fouling, metals such as copper and lead build up and moisture over the time. Cleaning is essentially required to avoid the malfunction of firearm which may lead to serious accidents [3, 4]. Malfunctions also include a slam fire, a misfire, hang fire and incomplete fire due to powder build up in the barrel [5, 6]. Thermal, mechanical, and chemical factors may damage the gun barrel due to this accumulation of sludge, carbon and metal particles [7, 8]. Cleaning with normal acidic or alkaline chemical based cleaners may lead to the corrosion thereby cracking of the barrel material and these cracks may act like stress risers and cause an approximately five times more increase on the barrel [9].

To prevent these type of accidents and malfunctions a regular cleaning of the forearm is very much necessary and at the same time the ingredients used should be of environmental friendly. There are different methods of cleaning a firearm which can range from a simple brush or solvent soaked to a complete detailed takedown and washing of parts [10].

A specially designed solvent penetrates and spreads along metal surfaces into every pit and crevice to undercut contamination and lift residue away where it can be removed. Normal solvents including water do not clean enough required to pull out or etch out oxide film, carbon and other gun powder particles etc. effectively. The chemical compositions formulated must do so without corroding, dissolving, or dulling the metal surface; chemically altering the substrate; or attacking the substrate itself. The compositions are aqueous, acidic compositions containing fluoride and organic polar solvents (water soluble). The resulting solvents are of low surface tension (< 30 mN/m at 25°C), low viscosity (< 10 centipoises at 25°C) which may either be slightly acidic or basic. The compositions are free of glycols making them to have a low surface tension and viscosity. Corrosion inhibitors present prevent the formation of metal oxide layer or rust on all metal parts present in the firearm [11, 12]. There are also automated methods of cleaning but not in reach for every organization [1]. The scientific community has been working continuously on developing new formulae [11]. There would be a universal cleaning formula for cleaning all weapons and feature [14].

There is high demand for a proper and safe liquid cleaner to remove complex contamination such as carbon deposits, copper residues, lead particles etc. from firearms after repeated usage in army, police department and armament factories of Ethiopia as normal acidic and caustic cleaners may corrode and damage the firearm material. Hence it is needed to formulate an effective and safe cleaning liquid for small firearms [15].

### Water based cleaning liquids

Aqueous cleaners are designed to reduce the surface tension of the water and also to provide a chemical reaction with the type of soils it is designed to remove [16, 17]. The chemicals in an aqueous cleaner may vary from soaps to surfactants to acids or chelating agents, builders, saponifiers, alkaline or combinations of the above. The cleaning solutions may be Ionic or non-Ionic dependent on the application. De-ionized water (DI) itself can be an effective cleaning agent in some circumstances. It is always preferable to use DI water as the major portion of the cleaning fluid as it is pure water and does not have minerals or other contaminants in it. It provides an excellent

vehicle for the detergent and there no chance of depositing minerals on the substrate. This will aid in the rinsing of the detergent and will provide spot free drying.

### Water/Solvent based Cleaners

Generally solvent based cleaners are denser and have lower surface tension than water and work on the basis of dissolving the organic/inorganic contaminants [18]. The solvents penetrating action as well as its chemical action remove inorganics, solvents can be blended, Azeotrope's or mixtures of both solvent and water. In our present study, owing to all positives and negatives of the cleaning agents discussed above, we have selected the combinations of various properties of the cleaning liquids and formulated unique cleaning liquids by blending the various chemicals in different proportions.

## II. MATERIALS AND METHODS

### Acidic Water/organic solvent based cleaners - Formulation-1

Method [19]:

1. An ideal pH of 6 was created by mixing 52mL of 0.1 M acetic acid and 948 mL of 0.1 M ammonium acetate.
2. De-ionized water was used throughout the research work.
3. Dimethylacetamide (DMAC),  $\text{CH}_3\text{C}(\text{O})\text{N}(\text{CH}_3)_2$  is used (60% wt.) as a polar organic solvent which also reduces the surface tension of the cleaning liquid.
4. This is a colorless, water-miscible, high boiling which is intended to remove all organic based dirt like oils, greases etc.
5. Monoethanolamine,  $\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{OH}$ , (1% wt) functions as a scrubbing agent and also to provide the alkalinity needed to protect the object against corrosion.
6. Ammonium fluoride,  $\text{NH}_4\text{F}$  (0.5%) to increase etching activity of the cleaning liquids to clean the object from silica contaminants, if present.
7. Anthranilic acid (or o-amino-benzoic acid) is an aromatic acid with the formula  $\text{C}_6\text{H}_4(\text{NH}_2)(\text{CO}_2\text{H})$ , (1%) added to improve the anti-rusting properties of the object cleaned in a longtime use.
8. Sodium tetra borate,  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$  (1%) boosts the detergent properties of the cleaning liquid and also increase co-complexing ability of borate with other agents in water to form complex ions with various substances.
9. Disodium hydrogen phosphate, is the inorganic compound with the formula  $\text{Na}_2\text{HPO}_4$ , (1%) acts as an emulsifier and also prevents the scale formation on the object cleaned as well as in the stainless steel cleaning tank.

#### ➤ Steps involving experimental procedure for Formulation-1

- 1.5 ml of 0.1 M acetic acid was mixed with 250 ml of water
- 7.708g of ammonium acetate was dissolved with 100 ml of DI water (1 M)
- From the above preparation, a dilution of 62 ml of acetic acid was mixed with 288 ml of ammonium acetate (Solution-1) Solution's pH was adjusted to 6

Then the following chemicals were added to the solution-1:

- Dimethylacetamide (DMAC),  $\text{CH}_3\text{C}(\text{O})\text{N}(\text{CH}_3)_2$ , (60% wt. aqueous solution)
- Monoethanolamine,  $\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{OH}$ , (1% wt aqueous solution)
- Ammonium fluoride,  $\text{NH}_4\text{F}$  (0.5% aqueous solution)
- Anthranilic acid (1% aqueous solution)
- Sodium tetra borate,  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$  (1% aqueous solution)
- Disodium hydrogen phosphate (1% aqueous solution)
- Isophthalic acid (1% aqueous solution)

### Formulation-2

Method [20, 21]

1. Acetic acid (28% aqueous solution)
2. Hydrogen peroxide (8% aqueous solution)

- Acetic acid is an oxidizing agent of lead layer
- Hydrogen peroxide is a chelating (complexing) agent for lead ions
- The diluted acetic acid mixed with hydrogen peroxide to form effective cleaning liquid at 35°C

This formulation specially focuses on lead particles present besides general cleaning.

**Formulation-3****Method**

*Required chemicals and their quantities:*

1. Automatic transmission fluid (Mobil type F) (25%)
2. Kerosene (low odor) (25%)
3. Aliphatic mineral sprit (n- hexane or n- heptane) (25%)
4. Acetone (25%)

- Auto transmission fluid is a lubricant which is always good for guns; it also contains a range of solvents designed to clear away metal particles that collect in a well-used gun
- Kerosene is another solvent, a more general-purpose one
- Mixed them in a well-ventilated area to work in

The chemicals mentioned above are volatile and flammable. Proper safety precautions have been maintained. In a well ventilated area and in a stainless steel container mixed all the ingredients in the same proportions.

**Formulation - 4**

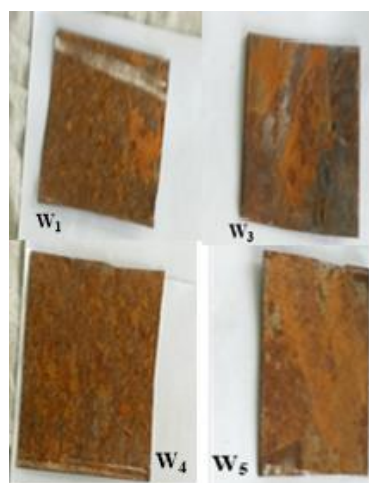
*Required chemicals and their quantities:*

1. Acetone (45%)
2. Heptane (20%)
3. Toluene (30%)
4. Carbon dioxide (gas)
5. Methanol (3%)

- *Acetone* is a common cleaner most nail polish removers are nearly 100% Acetone.
- *Heptane* is a well-known oil dissolving agent.
- *Toluene* is a common solvent used in a variety of paints, paint thinners, silicone sealants, rubber, printing ink, glues, and disinfectants.
- *Methanol* is also a well-known solvent that blends well with other chemicals.
- Carbon dioxide acts as the propellant for the aerosol.

**III. RESULTS AND DISCUSSION****Testing of cleaning liquid**

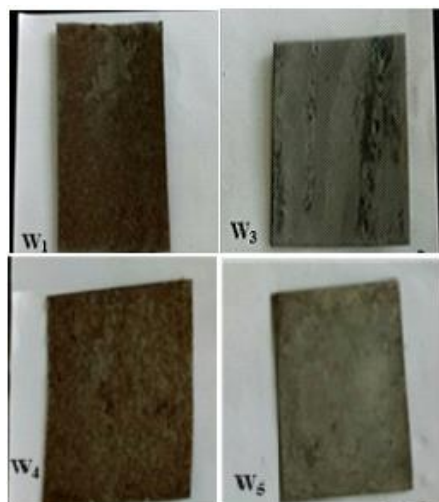
The four cleaning liquids prepared by aforementioned methods have been tested for their effectiveness [22, 23]. During the testing we noticed the formulations which show effectiveness in cleaning and accordingly they have been ranked. The test findings have been presented in the following figures and tables and suitable reasons were also discussed. However, as per our observation the formulation-4 is most effective and required in smaller as larger quantiles are prohibitive and unmanageable. It has been tasted and shown to exhibit very low non-volatile residue, fast evaporating, non- flammable and effective cleaning solvent.



Where:

- W<sub>1</sub> – Work piece to be cleaned by formulation-1
- W<sub>3</sub> – Work piece to be cleaned by formulation-2
- W<sub>4</sub> – Work piece to be cleaned by formulation-3
- W<sub>5</sub> – Work piece to be cleaned by formulation-4

**Fig. 1 Individual metal work pieces before application of formulations**



Where:

- W<sub>1</sub> – Work piece cleaned by formulation-1
- W<sub>3</sub> – Work piece cleaned by formulation-2
- W<sub>4</sub> – Work piece cleaned by formulation-3
- W<sub>5</sub> – Work piece cleaned by formulation-4

**Fig. 2 Individual metal work pieces after application of formulations**



**Fig. 3 Metal sheet specimen for comparative results before application**



**Fig. 4 Metal sheet specimen for comparative results after application of various formulations**





Fig. 5 Part of a pistol before cleaning




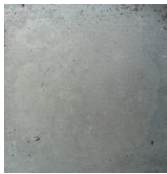


Fig. 6 Part of the same pistol after application of formulation-4



Fig. 7 Carbon ignition test for the removal of carbon

Table 1 Carbon Removal Test Results




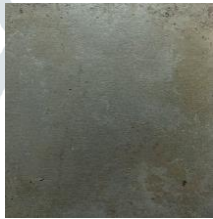
Formulation	Carbon Removal	Result in Picture	Formulation	Carbon Removal	Result in Picture
1	Yes		3	Yes	
2	Yes		4	Yes	

Results in Table-1 clearly shows that the formulations, -2 and -4 removed carbon perfectly followed by -1 and -3.

#### After-rust test (Corrosion Test)

Using the sample strip from the above test the sample was allowed to remain exposed to air at 50% relatively humidity for 48 hours. Results were presented in Table-2.

Table 2 Rust or Corrosion Test Results

Formulation	Corrosion Level	Result in Picture	Formulation	Corrosion Level	Result in Picture
1	Slight		3	Slight	
2	None		4	None	

The results obtained clearly showing that metal specimens treated with formulations -2 and -4 do not show any oxide layer (corrosion) formation even after a month of treatment whereas -1 and -3 shows a slight oxide layer formation.

#### IV. CONCLUSION

The following conclusion was drawn from the experimental results of gun cleaners produced using 4 different formulations. Though all the formulations have served their purpose of production but formulation-2 and formulation-4 were excellent in their jobs. The carbon removal test also proved that carbon deposits were removed from the work pieces. After-rust test showed that the work pieces cleaned by formulations -2 and -4 do not result in any rust formation even after one month. However, work pieces treated with -1 and -3 have shown slight rust formation after a month of treatment. In conclusion, we chose formulation-2 and formulation-4 where cleaning situation in which larger quantities are prohibitive and unmanageable. These two formulations have been tested and have shown to exhibit very low non-volatile residue, fast evaporating, none, flammable, powerful and effective cleaning solvent. Based on the results obtained formulations were ranked as F-1 < F-3 < F-2 < F-4.

#### V. ACKNOWLEDGEMENT

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