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Effects Of Salt, Vinegar And Bleach In Accelerating Rusting Of Iron

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***Abstract:** This investigation is primarily focusing on the effect of salt, vinegar and bleach in accelerating rusting of an iron. We use nails, common salt, bleach powder and five percent vinegar solution. The nails are partially immersed in the solutions contained in petri dishes labeled A to G and in the distilled water contained in petri dish 'H'. Petri dish 'A' contains 30mls bleach solution of 66.66g/dm^3 concentration, Petri dish 'B' contains 30mls of five percent vinegar solution, Petri dish 'C' contains 30mls salt solution (common salt) of 66.66g/dm^3 concentration. Petri dish 'D' contains 30mls of five percent vinegar solution dissolves 2g of bleach powder. Petri dish 'E' contain 30mls solution dissolves 2g of bleach powder and 2g of salt. Petri dish 'F' contain 30mls of five percent vinegar solution dissolves 2g of salt (common salt). Petri dish 'G' contain 30mls of five percent vinegar solution dissolves 2g of bleach powder and 2g of salt. Petri dish 'H' contain distilled water only. The weight of the nails contained in each petri dish is recorded after every 24 hours for seven days. The results obtained are interpreted and discussed through different graphs. The results show that the rate of rusting on the nails contained in petri dish 'D' is highest followed by nails contained in petri dish 'A', followed by nails contained in petri dish 'E', followed by nails contained in petri dish G, followed by nails contained in petri dish C, followed by nails contained in petri dish F, followed by nails contained in petri dish B and lastly the nails contained in petri dish H which show the least rate of rusting. This brings the conclusion that, bleach, common salt and vinegar accelerate the rate of rusting.**

I. INTRODUCTION

Some scholars have explained rust in relation to corrosion as follows

Sanjay PS (2015) studied the effect of metal coupling on the rusting of an iron. His report illustrated metal coupling effects the rusting of an iron. If the nail is coupled with the a more electropositive metal like zinc, magnesium or aluminum rusting is prevented but if on the other hand, it is coupled with less electropositive metals like copper, the rusting is facilitated. He concluded that coupling of iron with more electropositive metals such as zinc and magnesium resists corrosion and rusting of an iron. Coupling of iron with less electropositive metals such as copper increases rusting.

Gupta (2016), reported on rusting process. Rusting is a chemical process, which is common with the metals containing iron. In other words, the corrosion process taking place when there is iron, it is known as rusting. For rusting to take place, there should be certain conditions. In the presence of oxygen and moisture or water, iron undergoes this reaction and form a series of iron oxide. This reddish-brown color compound is known as rust. So, rust contains hydrated iron (III) oxide$Fe_2O_3.nH_2O$ and iron (III) oxide-hydroxide ($FeO(OH)_2.Fe(OH)_3$).If rusting starts at one place, it will eventually spread, and the whole metal will be disintegrated. Not only iron, but the metals containing iron(alloys) also undergo rusting. Rusting begins with the transfer of electrons from iron to oxygen. Iron atoms transfer two electrons and form iron (II) ions as follows.

$Fe \rightarrow Fe^{2+} + 2e^-$ -------------------------------------(i)

Oxygen forms hydroxide ions by accepting electrons in the presence of water.

$O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$ ----------------------(ii)

Above reactions are accelerated in the presence of acids. Further, when there are electrolytes like salts, the reaction is further enhanced. Rust contains iron (III) ions, so the formed Fe^{2+}undergoes redox reaction, to give Fe^{3+} as follows.

$4\ Fe^{2+} + O_2 \rightarrow 4\ Fe^{3+} + 2O^{2-}$ ------------------(iii)

Fe^{3+} and Fe^{2+} undergo following acid base reactions with water.

$Fe^{2+} + 2\ H_2O \rightleftharpoons Fe(OH)_2 + 2H^+$ -------------(iv)

$Fe^{3+} + 3\ H_2O \rightleftharpoons Fe(OH)_3 + 3\ H^+$ -------------(v)

Ultimately, a series of hydrated iron oxides is formed as rust.

$Fe(OH)_2 \rightleftharpoons FeO + H_2O$ ------------------------------------(vi)

$Fe(OH)_3 \rightleftharpoons FeO(OH) + H_2O$ -----------------------(vii)

$2FeO(OH) \rightleftharpoons Fe_2O_3 + H_2O$ ------------------------(viii)

Rybolt and Mebane (2010) Have investigated on effect acid rain on materials. Acid rain causes corrosion on metals such as iron which rusts. You may see corrosion (rust) on the nails in the vinegar in just the few hours. Most unprotected metals corrode when exposed to air and water. Acid like that found in acidic rain, can accelerate the corrosion of metals. He observed how the acids in vinegar corrodes iron. The amount of acid in vinegar is approximated 100 times more than what is found in acidic rain around many urban areas. By using a strong acid in this experiment, you can observe the corrosive effect of acid on metals more rapidly.

According to Zarras and Smith (2014) Corrosion is a naturally occurring development, typically defined as degradation of the material properties as a result of its interaction with the environment over a period of time. This definition is true for any type of material including plastics, however it is often reserved for metallic alloys. In the region 80 of the known chemical elements are metals (Figure 1). Of these metals roughly half can be alloyed with other metals, the subsequent composition of the alloy will determine the physical, chemical and mechanical properties (Speight, 1st Edition). The literature illustrates that the corrosion resistance of alloys such as stainless steels can be ignificantly enhanced by appropriate alloying (Olsson and Landolt, 2003).

The surface of all metals with the exception of gold contains an oxide film when in air. This protective oxide film has a tendency to dissolve when submerged in an oxidizing environment, exposing the bare metal surface resulting in a susceptibility to corrosion (Hinds). However a passive film is formed during the bare metal surface exposure which will reduce the reaction rate of the corrosion by several orders of magnitude Electrochemistry of Corrosion

The discussion of the electrochemistry of corrosion below has been summarized from the literature found in (Hinds). In the case where an oxide film has dissolved entirely with the metal surface exposed to the oxidizing solution, the positively charged metal ions will transfer from the metal into the solution, leaving electrons behind on the metal i.e.

The left over electrons in the metal lead to an increase in negative charge resulting in an electrode potential between the metal and solution, which in turn becomes further negative. As the electrode potential changes the reaction that was taking place above is slowed down until it is reversed with the deposition of dissolved metals ions from the solution on the metal surface now being encouraged i.e. A stable potential also known as the reversible potential (Er) is achieved when the rate of dissolution of metal ions becomes equal to the rate of deposition i.e. Where, Eo is the standard reversible potential, Mn^+ the unit activity of dissolved metal ions, R the gas constant, T the absolute temperature, F the Faraday and the number of electrons transferred per ion. No further metal dissolution is witnessed once the potential reaches the reversible potential. Typically only a very small quantity of metal is dissolved during this process.

However the reverse potential is not often reached and the potential stays more positive due to other reactions which are removing the electrons from the metal. For example, in acid solutions hydrogen gas is produced as the electrons react with hydrogen ions that have been absorbed on the metal surface from the solution.

II. METHODOLOGY

APPARATUS AND MATERIALS

In order to successfully conducting the experiment, the following apparatus and materials were used. Apparatus used are as follows;

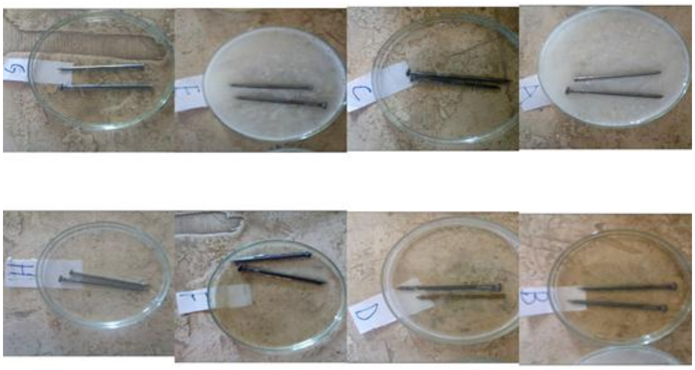
✓ Petri dishes
✓ Measuring cylinder
✓ Digital weighing Balance [measures up 2 decimal places]
✓ Spatula
✓ Dropper
✓ Bleach powder
✓ Vinegar
✓ Salt (NaCl)
✓ Nails (3 inches)
✓ Distilled water

PROCEDURES

The procedures were described below.

✓ Firstly, eight Petri dishes are cleaned and labeled letter A to H.
✓ A solution of 30mls made of 2gram (g) of bleach and water are put in Petri dish labeled A
✓ Then 30mls of vinegar is put in Petri dish labeled B
✓ A solution of 30mls made of 2g of salt and distilled water are put in Petri dish labeled C
✓ A solution of 30mls made of 2g of bleach and vinegar are put in Petri dish labeled D
✓ A solution of 30mls made of 2g of bleach,2g of salt and water are put in Petri dish labeled E
✓ A solution of 30 mls made of 2g of salt and Vinegar are put in petri dish labeled F
✓ A solution of 30 mls made of 2g of bleach,2g of salt and Vinegar are put in petri dish labeled G
✓ Then 30mls of distilled water is put in petri dish labeled H
✓ 16 nails are well cleaned with the help of sand paper
✓ A pairs of nails is carefully measured and the data is recorded.
✓ A measured pair of nails is put in each petri dish from A to H and left for 24 hours

- ✓ The mass of each pair of nails is measured after cleaning [removing rust] for every after 24 hours and the data is recorded



first day

III. DATA COLLECTION AND DISCUSSION

A. INTRODUCTION

This chapter is descriptive and designed to give out the outline of data collected from the petri dishes labeled A to H in relation to the mass change in seven days. Before measuring the weight a nail is removed from the petri dish and washed with clean water. Rusted parts are removed when washing. Data were collected after every twenty four hours.

B. OBSERVATION AND RESULTS

Petri Dish	Initial mass (g)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
A	13.41	13.22	13.16	13.13	13.1	13.08	13.06	12.9
B	13.19	13.18	13.15	13.14	13.1	13.07	13.06	13.05
C	13.11	13.08	13.03	12.95	12.93	12.91	12.79	12.76
D	13.12	12.89	12.83	12.8	12.77	12.73	12.69	12.49
E	13.09	12.96	12.94	12.91	12.89	12.87	12.85	12.82
F	13.39	13.36	13.33	13.3	13.27	13.24	13.21	13.18
G	13.12	13.02	12.97	12.93	12.89	12.85	12.79	12.76
H	13.15	13.14	13.13	13.1	13.09	13.08	13.07	13.06

Table 4.1: mass change of nails from petri dish A to H in seven days

Petri Dish	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
A	1.4169	1.8643	2.088	2.3117	2.4609	2.61	3.8031
B	0.0758	0.3033	0.3791	0.6823	0.9098	0.9856	1.0614
C	0.2288	0.6102	1.2204	1.373	1.5256	2.441	2.6697
D	1.753	2.2104	2.439	2.6677	2.9726	3.2774	4.8018
E	0.9931	1.1459	1.3751	1.5278	1.6807	1.8335	2.0626
F	0.224	0.4481	0.6721	0.8962	1.1202	1.3443	1.5683
G	0.7622	1.1433	1.4482	1.753	2.0579	2.5152	2.7439
H	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.2: Percentage mass change of nails from petri dish A to H in seven days

C. INTERPRETATION AND DISCUSSION

- ✓ Consider petri dish ‘A’ which contains nails that are partially immersed in 30mls bleach solution of 66.66 g/dm^3 concentration and petri dish ‘H’ which contain nails that are partially immersed in distilled water. Rate of rusting in petri dish ‘A’ is higher than the rate of rusting in petri dish ‘H’. This can be explained by the fact that, active ingredient in bleach is a chemical compound called sodium hypochlorite. It acts as an oxidizing agent, ionizing other materials by removing electrons from them; this is why it removes stains from clothes and kills germs. The oxidizing properties of bleach accelerate rusting; iron loses electrons more readily in the presence of bleach than in plain water.

	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7
Petri dish ‘A’	1.4169	1.8643	2.088	2.3117	2.4609	2.61	3.8031
Petri dish ‘H’	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.3: Mass change in percentage of petri dish A and H in seven days

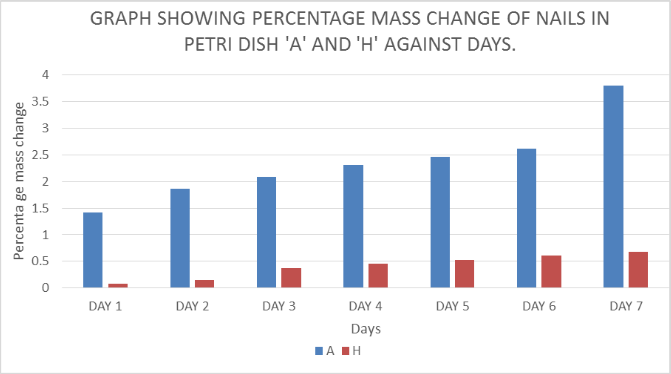


Figure 4.1: Percentage mass change of nails in petri dish A and H against Days

- ✓ Consider petri dish ‘B’ which contain nails that are partially immersed in 30mls of five percent (5%) vinegar solution and petri dish ‘H’ which contain nails that are partially immersed in distilled water. Rate of rusting in petri dish ‘B’ is higher than the rate of rusting in petri dish ‘H’. This is explained by the fact that, vinegar speeds up rusting because it contains a dilute form of acetic acid; positive hydrogen ions in the acid remove electrons from iron, ionizing it and making it susceptible to rust. Vinegar in water also conducts electricity better than water alone, facilitating the movement of electrons and ions during the rusting process. Although bleach and vinegar both accelerate rusting, do not combine the two, as the mixture releases toxic chlorine gas.

	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7
Petri dish ‘B’	1.4169	1.8643	2.088	2.3117	2.4609	2.61	3.8031
Petri dish ‘H’	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.4: Mass change in percentage between petri dish B and H in seven days

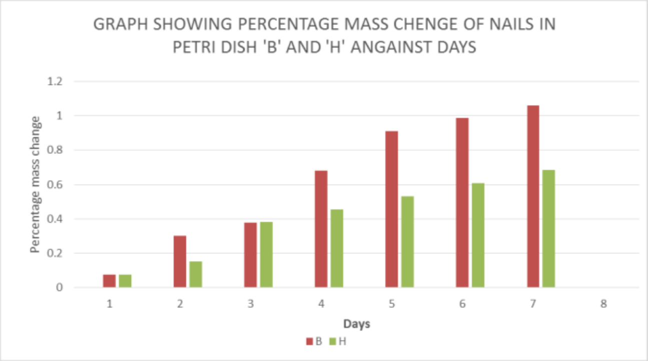


Figure 4.2: Percentage mass change of nails in petri dish B and H against Days

✓ Consider petri dish ‘C’ which contains nails that are partially immersed in 30mls salt solution (common salt) of 66.66 g/dm^3 concentration and petri dish ‘H’ which contain nails that are partially immersed in distilled water. Rate of rusting in petri dish ‘C’ is higher than the rate of rusting in petri dish ‘H’. This can be explained by the fact that, salt accelerates the rusting process by lowering the electrical resistance of water. Rust happens through a chemical process called oxidation in which metal atoms lose electrons, forming ions. The more easily the electrons flow from iron to oxygen, the quicker the metal rusts. In those states that use road salt during the winter to melt snow, steel car bodies rust more rapidly than in dry desert states.

	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7
Petri dish ‘C’	0.2288	0.6102	1.2204	1.373	1.5256	2.441	2.6697
Petri dish ‘H’	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.5: Mass change in percentage between petri dish C and H in seven days

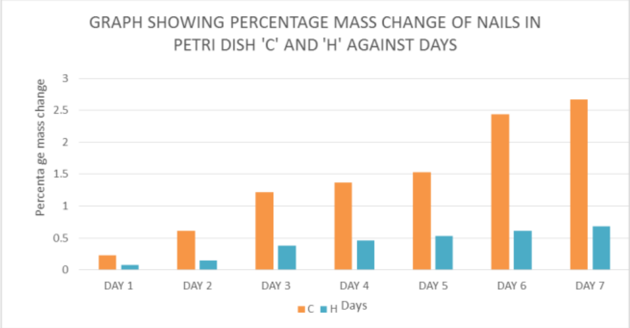


Figure 4.3: Percentage mass change of nails in petri dish C and H against Day

✓ Consider petri dish ‘D’ which contains nails that are partially immersed in 30mls of five percent vinegar solution dissolves 2g of bleach powder and petri dish ‘H’ which contain nails that are partially immersed in distilled water. Rate of rusting in petri dish ‘D’ is higher than the rate of rusting in petri dish ‘H’. This can be explained by the fact that, bleach is a chemical compound called sodium hypochlorite. It acts as an oxidizing agent, ionizing other materials by removing electrons from them. The oxidizing properties of bleach accelerate rusting; iron loses electrons more readily in the presence of bleach than in plain water. Vinegar speeds up rusting because it contains a dilute form of acetic acid; positive hydrogen ions in the acid remove electrons from iron, ionizing it and making it susceptible to rust. Vinegar in water also conducts electricity better than water alone, facilitating the movement of electrons and ions during the rusting process. Mixing bleach and vinegar the acid react with bleach releasing chlorine gas in small amount the chlorine gas reacts immediately with iron to give iron chloride, which looks like rust. If you add excess amount, however toxic chlorine gas might possibly be released.

	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7
Petri dish ‘D’	1.753	2.2104	2.439	2.6677	2.9726	3.2774	4.8018
Petri dish ‘H’	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.6: Mass change in percentage between petri dish D and H in seven days

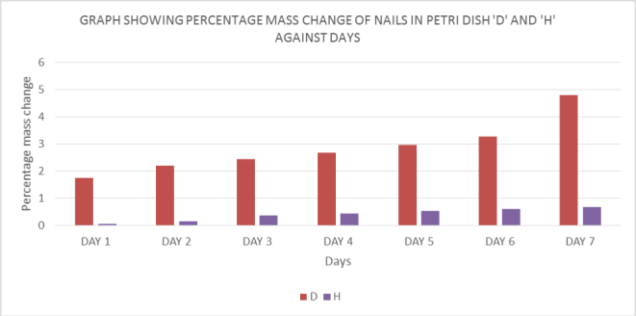


Figure 4.4: Percentage mass change of nails in petri dish D and H against Days

✓ Consider petri dish ‘H’ which contain nails that are partially immersed in distilled water and petri dish ‘E’ which contains nails that are partially immersed in 30mls solution, dissolves 2g of bleach powder and 2g of salt. Rate of rusting in petri dish ‘E’ is higher than the rate of rusting in petri dish ‘H’. This can be explained by the fact that, salt accelerates the rusting process by lowering the electrical resistance of water. Rust happens through a chemical process called oxidation in which metal atoms lose electrons, forming ions. The more easily the electrons flow from iron to oxygen, the quicker the metal rusts. Bleach acts as an oxidizing agent, ionizing other materials by removing electrons from them. The oxidizing properties of bleach accelerate rusting therefore the iron loses electrons more readily.

	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7
Petri dish ‘E’	0.9931	1.1459	1.3751	1.5278	1.6807	1.8335	2.0626
Petri dish	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.7: mass change in percentage between petri dish E and H in seven days

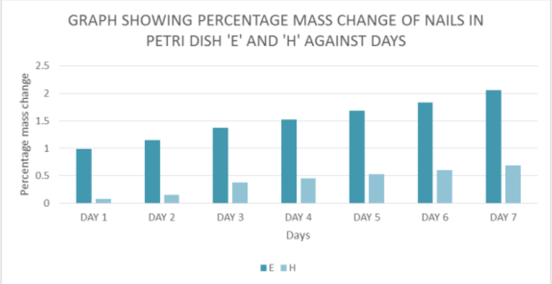


Figure 4.5: Percentage mass change of nails in petri dish E and H against Days

- ✓ Consider petri dish ‘F’ which contains nails that are partially immersed in 30mls of five percent vinegar solution dissolves 2g of salt (common salt) and petri dish ‘H’ which contain nails that are partially immersed in distilled water. Rate of rusting in petri dish ‘F’ is higher than the rate of rusting in petri dish ‘H’. This can be explained by the fact that, salt accelerates the rusting process by lowering the electrical resistance of water. Rust happens through a chemical process called oxidation in which metal atoms lose electrons, forming ions. The more easily the electrons flow from iron to oxygen, the quicker the metal rusts. Vinegar in water conducts electricity better than water alone, facilitating the movement of electrons and ions during the rusting process. Also because it contains a dilute form of acetic acid; positive hydrogen ions in the acid remove electrons from iron, ionizing it and making it susceptible to rust

	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7
Petri dish ‘F’	0.224	0.4481	0.6721	0.8962	1.1202	1.3443	1.5683
Petri dish ‘H’	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.8: Mass change in percentage between petri dish F and H in seven days

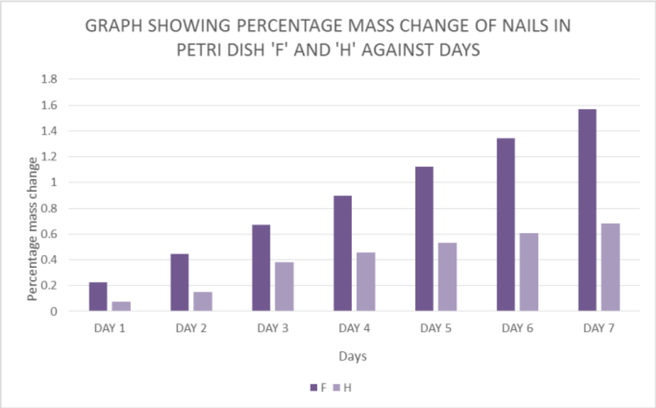


Figure 4.6: Percentage mass change of nails in petri dish F and H against Days

- ✓ Consider petri dish ‘H’ which contain nails that are partially immersed in distilled water and petri dish ‘G’ which contains nails that are partially immersed in 30mls of five percent vinegar solution, dissolves 2g of bleach powder and 2g of salt. Rate of rusting in petri dish ‘G’ is higher than the rate of rusting in petri dish ‘H’. This can be explained by the fact that, Bleach acts as an oxidizing agent, ionizing other materials by removing electrons from them. The oxidizing properties of bleach accelerate rusting therefore the iron loses electrons more readily. In the other side, salt accelerates the rusting process by lowering the electrical resistance of water. Rust happens through a chemical process called oxidation in which metal atoms lose electrons, forming ions. The more easily the electrons flow from iron to oxygen, the quicker the metal rusts. Vinegar also contribute the acceleration of rusting because it contains a dilute form of acetic acid; positive hydrogen ions in the acid remove electrons from iron, ionizing it and making it more susceptible to rust.

	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7
Petri dish ‘G’	0.762	1.1433	1.4482	1.753	2.0579	2.5152	2.7439
Petri dish ‘H’	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.8: showing mass change in percentage between petri dish G and H in seven days

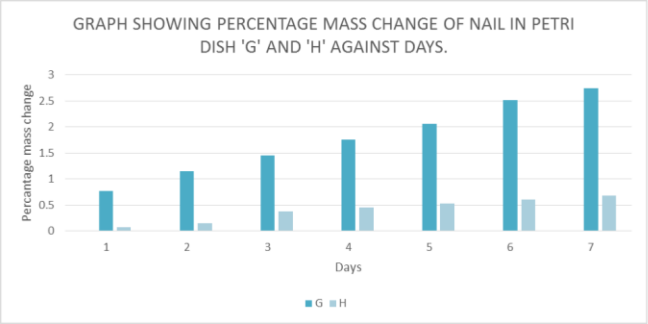


Figure 4.7 Percentage mass change of nails in petri dish G and H against Days

Petri Dish	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
A	1.4169	1.8643	2.088	2.3117	2.4609	2.61	3.8031
B	0.0758	0.3033	0.3791	0.6823	0.9098	0.9856	1.0614
C	0.2288	0.6102	1.2204	1.373	1.5256	2.441	2.6697
D	1.753	2.2104	2.439	2.6677	2.9726	3.2774	4.8018
E	0.9931	1.1459	1.3751	1.5278	1.6807	1.8335	2.0626
F	0.224	0.4481	0.6721	0.8962	1.1202	1.3443	1.5683
G	0.7622	1.1433	1.4482	1.753	2.0579	2.5152	2.7439
H	0.076	0.1521	0.3802	0.4563	0.5323	0.6084	0.6844

Table 4.9: Percentage mass change of nails

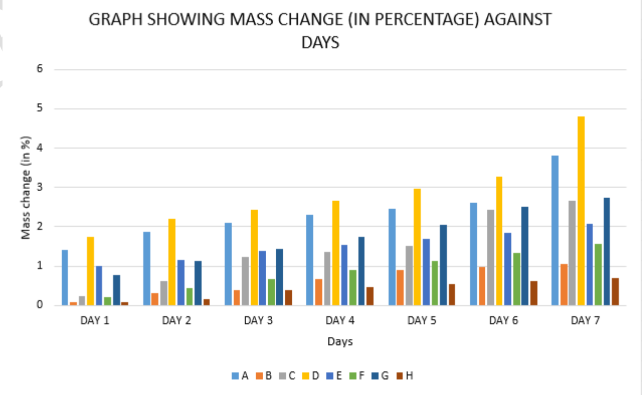


Figure 4.8: Mass change in percent of nails in petri dish from A to H in seven Days

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

It is clear from observation that, salt, vinegar and bleach accelerate rusting of an iron in different rates. These chemicals accelerate rusting by increasing the electrical activity between iron and oxygen. Substances such as salts and acids increase the conductivity of moisture around metal, making rust happen more quickly.

B. RECOMMENDATIONS

The experimental investigation conducted in this project has led to the conclusion that under suitable and more convenience presence of salt, vinegar and bleach can rapidly accelerate the rusting of iron in any environment (Exposure to outdoor conditions will increase the risk of rust, especially if the climate is rainy or humid).

Therefore it is recommended that further investigation must be done to discover other rusting prevention methods in various areas where rusting is likely to occur under presence of the chemicals samples mentioned, or otherwise the following methods must be applied for long life of iron tools;

Barrier protection. Barrier protection can be achieved by one of the following ways; by painting the surface, by coating the surface with a thin film of oil or grease, by electroplating iron with some non-corrosive metal such as nickel, chromium, copper, etc.

Sacrificial protection. In this method, surface of iron is covered with layer of more active metal like zinc. This active metal loses electrons (undergoes oxidation) in preference to iron and hence, prevents the rusting of iron. Zinc, magnesium and aluminum powder dissolved in paints can also be applied as protective layers. The well-known aluminum paint contains aluminum powder suspended in varnish.

Use of anti-rust solutions. The alkaline phosphate and alkaline chromate solutions act as anti-rust solutions. When iron articles are dipped into a boiling and strongly alkaline solution of sodium phosphate, a protective insoluble film of iron phosphate is formed on them. This film protects the article from rusting

Electrical protection. The metallic iron is connected with more active metals like magnesium or zinc. Active metal has lower reduction potential than iron and with lose electrons in preference to iron. This method is used for protecting iron articles which are in contact with water.

Other methods such as use of rust resistant alloys, proper design of iron tools, galvanization, bluing organic coating, powder coating and regular maintenance can be use.

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