Global Warming Triggered Heavy Rains and its Effect on the Corrosion of Car Bodies in Uyo Metropolis

Aondona Paul Ihom, Patrick Peters Obot, Ini Umoren Udofia

Global Warming Triggered Heavy Rains and its Effect on the Corrosion of Car Bodies in Uyo Metropolis

Aondona Paul Ihom[1, a], Patrick Peters Obot [2, b], Ini Umoren Udofia[3,c]

1 – Department of Mechanical Engineering, University of Uyo, Uyo, PMB 1017 Uyo- Nigeria

a – draondonaphilip@gmail.com

b – obotuv@yahoo.com

c – iniumoren@yahoo.com

DOI **10.2412/mmse.01.39.008** provided by Seo4U.link

Keywords: corrosion, cars, heavy rains, global warming, Uyo Metropolis.

ABSTRACT. Global warning has stimulated several weather conditions; in some parts of the world it is excessive drought, while in others it is excessive rains, cold and heat. This study looked at the effect of excessive rain on the corrosion of car bodies in Uyo metropolis; a city that has been witnessing heavy rains each year with floods occurring in some parts of the city. The study monitored corrosion in different types of cars, noting the materials used for the car body, the year of manufacture of the car, the maintenance culture of the user, the number of years it was used in the area understudy and the effect of corrosion on the different parts of the car body. The highlights of the study revealed that the most critically affected parts of the cars considered were the underneath, and hidden areas around overlapping parts of the cars. The top parts of most cars had faded paints which were almost giving way to corrosion. Steel bodies were affected more than aluminum car bodies. The study also noted that the effectiveness of the corrosion resistance performance of the coating work on the steel used at the underneath of the cars varied from one car manufacturer to another. The underneath corrosion varied from low to very high corrosion signs. The study however, did not include cars with wholly polymer composite bodies.

1. Introduction. In the paper presented at National Development Centre "Towards a Longer Lasting Car: The Corrosion Factor" the author [5] clearly outlined the sources of corrosion attack on the car, how to prevent the corrosion attack and the economics of corrosion attack on cars every year in Nigeria. The summary of his work was that to have a longer lasting car, the user must be in the habit of retouching his car, whenever he notices a damage coating or buy a car with plastic body. Frequent washing and waxing of the chrome is normally very helpful, and the use of inhibitors in the car cooling system should be encouraged. Short runs should be avoided. The fuel tank should be kept half full always and all forms of leakages on the car should be stopped immediately, and repairs carried out. The researcher also opined that much has to be done by the car manufacturer by way of materials selection [5].

Corrosion reduces the life span of cars, the effect is normally significant at coastal areas and cities with heavy rains. Corrosion according to [7] is like corruption if left unabated can destroy national economy. There have been times when cars and vehicles awaiting shipment or clearing at seaports were scrapped as a result of corrosion. The cars were attacked by the salt environment of the sea. The underneath of cars and door edges and hidden points, where water accumulates is commonly susceptible to corrosion [4, 3]. The south-south region as a result of global warming trigger rains coupled with environmental pollution from gas flaring has induced corrosion in autos. The level of pollution from this area is normally evident from dirty water with black suspension particles collected from roof tops, and black-spotted roof tops which the governor of the state said has caused most of his people to resort to the use of black roofing sheets to maintain aesthetics [7, 8]. Salted roads in cold areas of the world have also being another reason for the corrosion of cars. For corrosion to take place, air and moisture must be present. It therefore means that if any of these is excluded there won't

be corrosion [2]. Global warming have stimulated several weather conditions: in some parts of the world, it is excessive drought, while in others it is excessive rains, cold and heat. This is not without effects; excessive rains have varying degrees of effects both on living and non-living things [6, 7]. Muddy roads and acidic rains are encouraging the corrosion of cars, (see Fig. 1) this is because in most cities today the air is polluted particularly in the south-south region of Nigeria where gas flaring is going on in addition to the combustion of fossil fuels in various types of engines and cooking devices. The region as a result of global warming has been experiencing heavy rains for some years now with effects of flooding, muddy roads and dirty rain water [8].

Fig. 1. Underneath Corrosion Effect on a Car in Uyo-Nigeria.

According to corrosion exclusively [1] when owing a car in the seventies and eighties particularly if one lived along the south African coast, some years after purchasing the vehicle the body work would start to discolour and eventually rust. This would occur mostly along the edges of the windows, at the bottom of the doors, the sills under the doors and on the bonnet arising from stone dripping while driving. While we guess many complained about it to their car dealers and thought no one was taking any notice, the Japanese and Koreans car manufacturers in the late eighties and nineties who were looking to get a market share, listened and began their introduction to the market by offering 6-year corrosion warranty on their cars. North American-made vehicles were having "real rust problems" that couldn't be fought merely with heavier, and more expensive paint. By the mid-1980's, one really had to galvanise the whole car if you wanted to issue warranties. Zinc in one form or another had been used to protect steel used in automobiles since the 1970's but corrosion resistance was never a feature until the Japanese cars gained entrance to the US market in the early 1980's. Several generations of galvanised steels have been developed by steelmakers to meet the demand of automakers for a corrosion free car. Today hot dip free zinc and the zinc/ iron alloy galvanneal are the most common found sacrificial coatings in use by the global automotive industry. From the early 1980's until the mid 1990's, automotive manufacturers around the world were steadily increasing the amount of coated steels on their vehicles in order to improve corrosion resistance performance. The percentage of coated steel usage was steadily rising and had increased to 80% by the mid 1990's from a low of approximately 10%, in the early 1980's in North America. Currently 80-90% of the metal used in cars in North America and Europe is galvanized compared to just 30% in China, a level expected to grow. In North America, Japan, and Korea over half of all galvanized sheet production is destined for the automotive market, whereas, in other countries, the construction industry consumes

a larger share [1]. Nigeria is inclusive, the construction industry consumes a larger share of galvanized steel.

Some galvanized materials now offer corrosion resistance for 40-60 years, and research by some companies continues to find ever-more resistant options to help deal with problems that may be caused by extreme weather events and climate change [1].

Steel maker Voestalpine has developed zinc magnesium hot dip galvanized steel strip and a, galvannealed product which has both zinc and a zinc-iron alloy coating. According to the company, the zinc magnesium coating has, the highest degree of corrosion resistance and no limitations with respect to processing properties. Especially in the automotive industry zinc magnesium has the potential to become the standard product over the next decade, the Austria-based company said in an emailed statement: "A zinc magnesium galvanized product could then be a similar niche product like an electrolytic galvanized product is today" [1].

The above cited reviews clearly outlined the efforts made by steelmakers and auto-manufacturers to check automotive corrosion over the years, while a great deal has been achieved the menace is yet to be completely rooted out particularly with global warming and changing climatic weather conditions. Progress no doubt has been made over the years. Progressive automotive corrosion resistance has been achieved with newer cars having higher corrosion resistance than older cars or cars of older generation. Cars of the 80's are still in use particularly here in Nigeria. This work covers automobiles of different models and ages. The objective of the research is to uncover the effect of global warming motivated heavy rains on the corrosion of car bodies in Uyo metropolis, south-south Nigeria.

Materials and Method

Materials and Equipment

The materials used for this work were Japanese cars, Korean cars, American cars, and cars manufactured in Europe, specifically France and Germany. The equipment used were cranes for lifting and spanners of various sizes which were used in loosing of bolts and nuts to expose hidden parts of the cars for proper corrosion monitoring and inspection of the parts for corrosion effect. Camera was used to capture the image of inspected portions of the cars.

Method

The study of the effect of heavy rains on the corrosion of car bodies in Uyo metropolis was carried out by dividing the work into two parts. The first part was to carry out corrosion monitoring on car bodies. Corrosion monitoring and inspection was carried out on the exposed car body and some parts of the car body were dismantled to expose hidden parts for inspection and corrosion monitoring. The information captured were; car type, model, year of manufacture, corroding region, maintenance culture, corroding material and corrosion condition. The cars which were inspected were, American cars, Japanese cars, European cars from France, Germany, and Korean cars from South Korea, all these cars are imported into Nigeria. The second part of the work was corrosion monitoring and inspection of the underneath of cars. The inspection process requires turning the car up so that the underneath can be properly viewed as shown in Fig. 1. The same information was captured as in the first part of the work. Information on the maintenance culture was obtained from the car owners. The corrosion and attached mud condition of the underneath of the car was noted during the corrosion monitoring and inspection. Images of the corrosion effect were captured using a camera. Maintenance garages in Uyo metropolis and individual car owners made their cars available for the study.

Results and Discussion

The results of the findings of this work are displayed in Tables 1-2 and in Figs. 2-31.

Table 1. Corrosion monitoring of body of cars in Uyo metropolis in 2015.

S/N	Manufacturer	Model	Year	Maintenance Culture	Corroding Region	Corroding Material	Corrosion Condition
1.	BENZ	Flat.booth 200E	1975	Nill	Sides panel	Aluminium	Corroded
2.	PEUGEOT	SR 406	1985	When required	Roof/body/doors		Faded paint
3.	PASSAT	402	1985	When required	Doors/roof		Corroded
4.	BENZ	V.booth 230.E	1985	When required	Roof/burnet	Aluminium	Faded paint
5.	BENZ	V.booth 300E	1985	Nill	Roof/burnet	Aluminium	Faded paint
6.	BMW	E 30	1987	When required	Roof/bodydoors	Steel base	Faded paint
7.	VOLVO	240GL	1987	When required	Roof	;;	Faded paint
8.	NISSAN	Sunny 1.4L	1991	Nill	Roof/body	;;	Faded paint
9.	AUDI	Avant A6	1994	Yearly	Roof/body	;;	Less Effect
10.	TOYOTA	Camry 2.2GL	1996	Yearly	Roof/body	;;	Less Effect
11.	NISSAN	Almera 1.6SLX	1997	When required	Body	;;	Faded pait
12.	NISSAN	Almera 1.6SLX	1997	Nill	Doors/roof	;;	Corroded
13.	NISSAN	Blue Bird	1998	2 years ago	Roof/doors	;;	Faded paint
14.	TOYOTA	Corolla	1998	Just sprayed	Roof/body/doors	;;	No Effect
15.	TOYOTA	Camry LE	1999	When required	Roof/body/doors	;;	Faded paint
16.	TOTOTA	Camry LE	2000	When required	Body/roof	;;	Less Effect
17.	NISSAN	Almera Tino	2001	Nill	Roof	;;	Faded paint
18.	TOYOTA	Camry 2.2XL	2001	Just sprayed	Body/roof	;;	No Effect
19.	GOLF	3.0 Wagon	2001	When required	Body/doors	;;	Faded paint
20.	BENZ	BENZ 190	2002	When required	Roof/body	Aluminium	Faded paint
21.	NISSAN	Primera	2002	When required	Roof/body	;;	Faded paint
22.	NISSAN	Serena LMT	2002	When required	Roof/body	;;	Faded paint
23.	NISSAN	Sunny 1.6SLX	2002	Just sprayed	Roof/body	;;	No Effect
24.	TOYOTA	Corolla S	2003	Just sprayed	Roof/body	;;	No Effect
25.	TOYOTA	RAV4 S	2004	Nill	Roof/burnet	,;	Faded paint
26.	NISSAN	Pathfinder SE3.5	2005	Nill	Roof/body	;;	Faded paint
27.	KIA	Porter Jeep	2008	Nill	Roof/burnet	;;	Faded paint
28.	HONDA	Accord 2LX	2008	Nill	Roof/burnet	;;	Faded paint
29.	HYUNDAI	Accent	2008	Nill	Roof	;;	Faded paint
30.	TOYOTA	Hiace Bus	2009	Nill	Roof	;;	Faded paint

Table 2. Corrosion monitoring of underneath of cars in Uyo metropolis in 2015.

S/N	Manufacturer	Model	Year	Maintenance Culture	Corroding Region	Corroding Material	Corrosion Condition
1.	BENZ	Flat.booth 200E	1975	When required	Underneath	coated steel	Very high
2.	PEUGEOT	SR 406	1985	When required	Underneath	"	Very high
3.	PASSAT	402	1985	When required	Underneath	"	Very high
4.	BENZ	V.booth 230.E	1985	When required	Underneath	"	Very high
5.	BENZ	V.booth 300E	1985	Nill	Underneath	"	High
6.	BMW	E 30	1987	When required	Underneath	"	Very high
7.	VOLVO	240GL	1987	When required	Underneath	"	Medium
8.	NISSAN	Sunny 1.4L	1991	Nill	Underneath	"	Very high
9.	AUDI	Avant A6	1994	Yearly	Underneath	"	Medium
10.	TOYOTA	Camry 2.2GL	1996	Yearly	Underneath	"	Low
11.	NISSAN	Almera 1.6SLX	1997	5 years ago	Underneath	"	High
12.	NISSAN	Almera 1.6SLX	1997	Nill	Underneath	"	Very high
13.	NISSAN	Blue Bird	1998	2 years ago	Underneath	"	Medium
14.	TOYOTA	Corolla	1998	Yearly	Underneath	"	Very low
15.	TOYOTA	Camry LE	1999	When required	Underneath	"	Low
16.	TOTOTA	Camry LE	2000	When required	Underneath	"	Low
17.	NISSAN	Almera Tino	2001	Nill	Underneath	"	High
18.	TOYOTA	Camry 2.2XL	2001	When required	Underneath	"	Low
19.	GOLF	3.0 Wagon	2001	When required	Underneath	"	Low
20.	BENZ	BENZ 190	2002	When required	Underneath	"	Very high
21.	NISSAN	Primera	2002	When required	Underneath	"	Medium
22.	NISSAN	Serena LMT	2002	When required	Underneath	"	Very high
23.	NISSAN	Sunny 1.6SLX	2002	When required	Underneath	"	Medium
24.	TOYOTA	Corolla S	2003	Yearly	Underneath	"	Very low
25.	TOYOTA	RAV4 S	2004	3 years ago	Underneath	"	Medium
26.	NISSAN	Pathfinder SE3.5	2005	When required	Underneath	"	Low
27.	KIA	Porter Jeep	2008	Nill	Underneath	"	High
28.	HONDA	Accord 2LX	2008	Nill	Underneath	"	Low
29.	HYUNDAI	Accent	2008	Nill	Underneath	"	Medium
30.	TOYOTA	Haice Bus	2009	Nill	Underneath	"	High

Fig. 2. Corrosion Effect on different parts of a car body (Manufacturer: Mercedes-Benz Model: Flat booth 200 E, Year of Manufacture: 1975).

Fig. 3. Corrosion Effect on Different Parts of a Car Body (Manufacturer: Peugeot, Model: 504 SR Year of Manufacture: 1985).

Fig. 4 Corrosion Effect on Different Parts of a Car Body (Manufacturer: Volkswagen Model: Passat 402, Year of Manufacture: 1985)

Fig. 5. Corrosion Effect on Different Parts of a Car Body (Manufacturer: Mercedes-Benz Model: V booth 230 E, Year of Manufacture: 1985).

Fig. 6, Corrosion Effect on Different Parts of a Car Body (Manufacturer: Mercedes-Benz, Model: V booth 300 E, Year of Manufacture: 1985).

Fig. 7. Corrosion Effect on Different Parts of a Car Body (Manufacturer: BMW Model: E 30, Year of Manufacture: 1987).

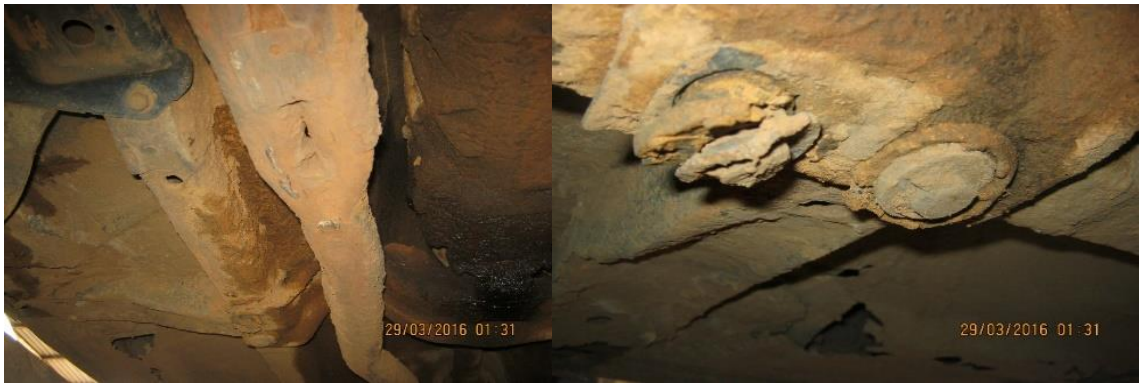

Fig. 8. Corrosion Effect on Different Parts of a Car Body (Manufacturer: VOLVO Model: 240GL, Year of Manufacture: 1987).

Fig. 9. Corrosion Effect on Different Parts of a Car Body (Manufacturer: NISSAN Model: Sunny 1.4L Year of Manufacture: 1991).

Fig. 10. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: AUDI Model: Avant A6, Year of Manufacture: 1994).

Fig. 11. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: Camry 2.2 GL, Year of Manufacture: 1996).

Fig. 12. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Almera 1.6 SLX, Year of Manufacture: 1997).

Fig. 13. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Almera 1.6 SLX, Year of Manufacture: 1997).

Fig. 14. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Blue Bird, Year of Manufacture: 1998).

Fig. 15. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: Corolla, Year of Manufacture: 1998).

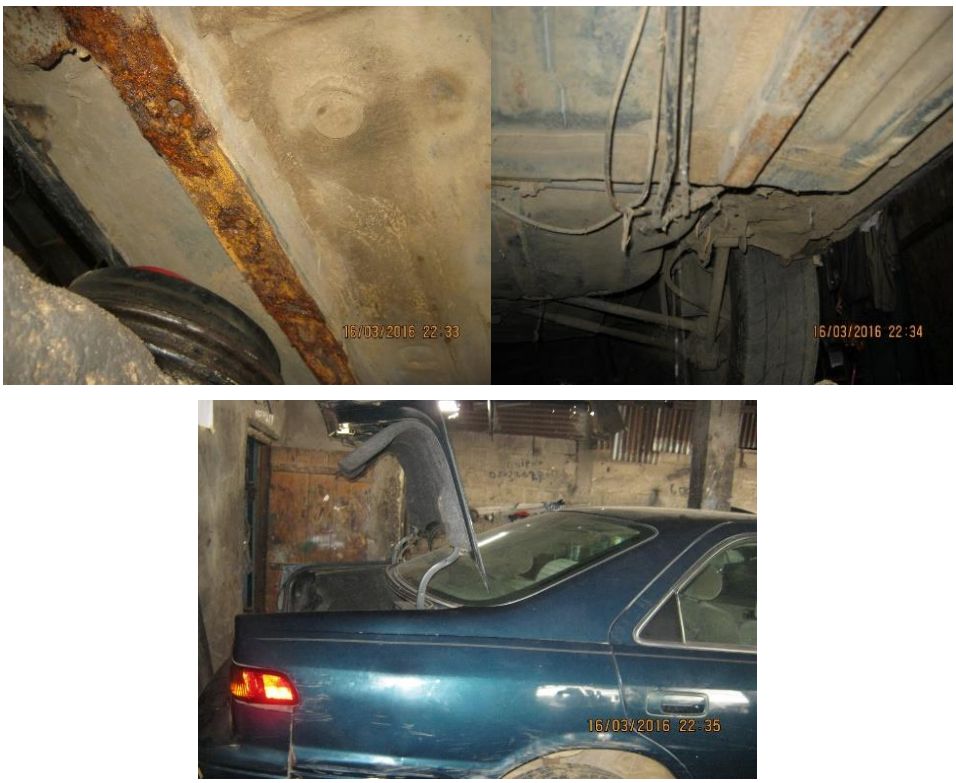

Fig. 16. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: Camry LE, Year of Manufacture: 1999).

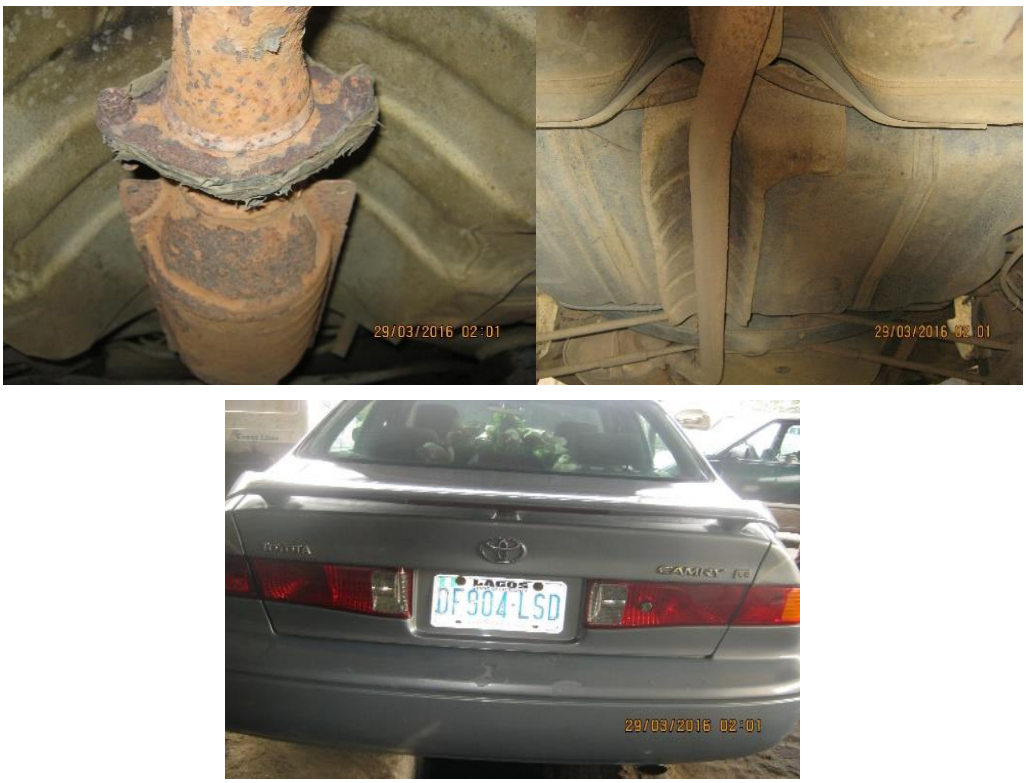

Fig. 17. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: Camry LE, Year of Manufacture: 1999).

Fig. 18. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Almera Tino, Year of Manufacture: 2001).

Fig. 19. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: Camry 2.2 XL, Year of Manufacture: 2001).

Fig. 20. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: Volkswagen Model: GOLF 3.0 Wagon, Year of Manufacture: 2001).

Fig. 21. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: Mercedes-Benz Model: BENZ 190, Year of Manufacture: 2002).

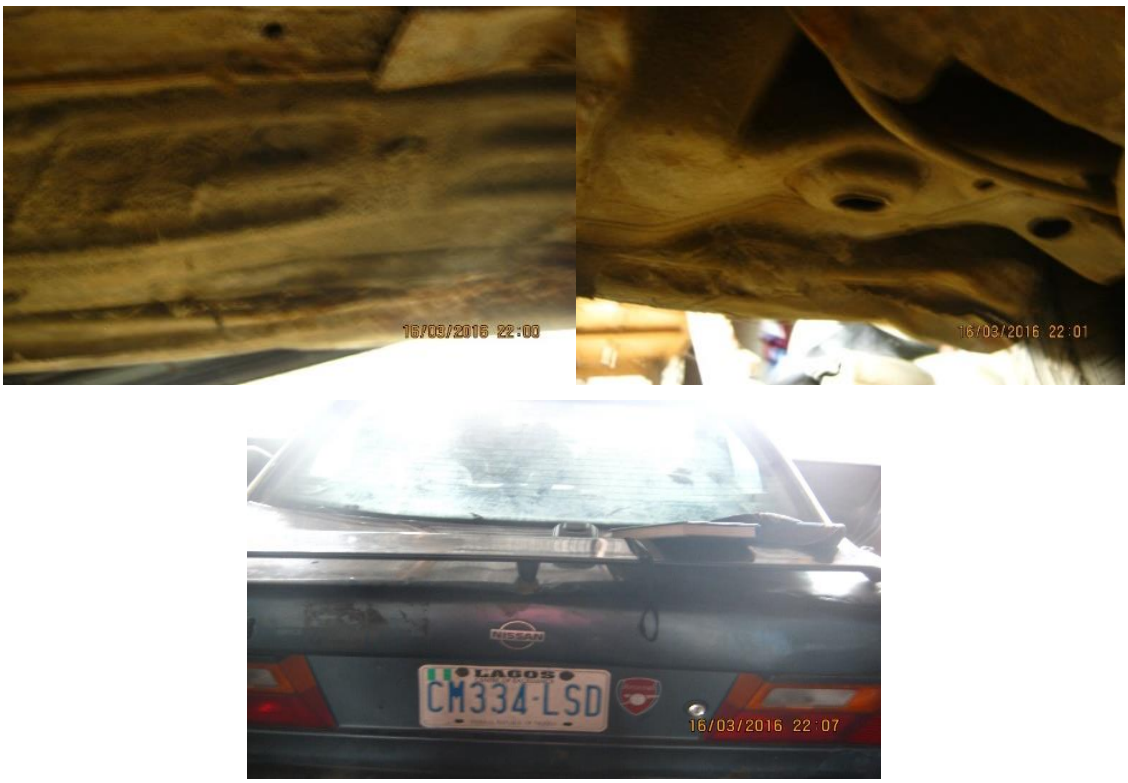

Fig. 22. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Primera, Year of Manufacture: 2002).

Fig. 23. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Serena LMT 200, Year of Manufacture: 2002).

Fig. 24. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Sunny 1.6SLX, Year of Manufacture: 2002).

Fig. 25. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: Corolla S Year of Manufacture: 2003).

Fig. 26. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: RAV4 S, Year of Manufacture: 2004).

Fig. 27. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: NISSAN Model: Pathfinder, S.E 3.5, Year of Manufacture: 2005).

Fig. 28. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: KIA Model: Porter, Year of Manufacture: 2008).

Fig. 29. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: HONDA Model: ACCORD 2.0 LX, Year of Manufacture: 2008).

Fig. 30. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: HYUNDAI Model: Accent, Year of Manufacture: 2008).

Fig. 31. Corrosion Effect on Different Parts of the Underneath of a Car (Manufacturer: TOYOTA Model: Haice bus, Year of Manufacture: 2009).

Discussion

Global warming activated heavy rains and its effect on the corrosion of car bodies in Uyo metropolis is a study that has been carryout as reflected in Tables 1-2 and Fig. 2-31. It is interesting to note that

Fig. 2-9 shows the images of corrosion on the car bodies that were investigated during the study as shown the result of Table 1. Fig. 10-31 are the images of corrosion of the underneath of cars investigated; the images support the result of the corrosion monitoring and inspection as shown in Table 2.

Global warming has activated or triggered heavy rains especially in coastal areas; hardly a day passes without rain falling in Uyo this situation has created muddy situation on the untarred roads in the city, trapped muds can be sighted on the underneath of some of the images shown in Fig. 10-31. Polluted air with gas flaring activities, emissions from gen-sets and autos have equally increased the aggressiveness of rain water, the effect on car bodies can be sighted in Fig. 2-9. Hidden areas where moisture is trapped by the cars are badly corroded as in Fig. 2, 5, and 7.

Fig. 10- 31 which are images of the underneath of the various cars investigated clearly shows that the underneath of the cars is badly affected. Critical areas include the exhaust system and areas where muds are trapped. Obviously most car manufacturers still need to work on their exhaust system material to make it more corrosion resistant. The problem of most exhaust system is not just wet corrosion but oxidation as a result of the high temperature of the exhaust gases. The effect of the heavy rains on car bodies as can be seen in the study has to do with fading paints.

Table 1 which is the result of the effect of heavy rains on car bodies in Uyo metropolis, considers various types of cars, materials used for the car body, their models, year of manufacture, maintenance culture, and the status of corrosion on the car body. The parameters considered normally contribute to the corrosion status of a car, it was however, not possible for the research to know the type of coating provided by the steel makers on the steel sheet used for the body of the cars. Looking at the year of manufacture of some of the cars it may be difficult to provide a true assessment of corrosion effect as a result of heavy rains and changing climatic conditions, particularly cars manufactured, in the 70's, 80's, and 90's since they have already lived a good part of their specified lifespans to be considered in a study that is conducted in 2015. The cars that should be of real concern here are cars manufactured from 2000-2015. The result in Table 1 show that for this group of cars the only effect noticed was faded body paint. No doubt this category of cars have benefited from the great improvement of coating work that have occurred over the years (Corrosion, 2015). Today hot dip free zinc and the zinc/ iron alloy galvanneal are the most common found sacrificial coatings in use by the global automotive industry. From the early 1980's until the mid-1990's, automotive manufacturers around the world were steadily increasing the amount of coated steels on their vehicles in order to improve corrosion resistance performance. The percentage of coated steel usage was steadily rising and had increased to 80% by the mid 1990's from a low of approximately 10%, in the early 1980's in North America. Currently 80-90% of the metal used in cars in North America and Europe is galvanized compared to just 30% in China, a level expected to grow. Some galvanized materials now offer corrosion resistance for 40-60 years, and research by some companies continues to find ever-more resistant options to help deal with problems that may be caused by extreme weather events and climate change.

Table 2 show the result of corrosion monitoring of underneath of cars in Uyo metropolis the same parameters as in Table 1 were consider during the monitoring; that being the case we maintain that for a fair assessment of the effect of heavy rains on the underneath of the investigated cars, only cars manufactured from 2000-2015 be considered. The result showed that some of the underneath of the cars show low corrosion, some medium, high, and very high; according to the scale of rating for the assessment. This may have to do with the type of coating provided by the steelmakers and the car manufacturers, not ruling out maintenance culture which has to do with frequent washing. This argument is predicated on the fact that some of the cars in Table 2 manufactured in 2001 showed low corrosion sign. The result has shown that the early signs of corrosion are a clear evidence of aggressive environment triggered by heavy and polluted rains. Acidic rains and muddy soils are normally very corrosive to the underneath of cars. As stated above some galvanized materials now offer corrosion resistance for 40-60 years, and research by some companies continues to find ever-more resistant options to help deal with problems that may be caused by extreme weather events and

climate change, therefore for cars manufactured from 2000 to 2015 to develop serious corrosion problem should elicit curiosity [1, 6-7].

Summary. The study "global warming activated or triggered heavy rains and its effect on the corrosion of car bodies in Uyo metropolis, has been carried out the study extensively investigated the effect of heavy rains on car bodies and the underneath of cars. Different types of cars manufactured by different companies with different years of manufacture were considered in the study, however for the assessment of the effect of heavy rains on the cars only cars manufactured from 2000-2015 were considered for the drawing of conclusions, and the following conclusions were drawn from the study:

1. The effect of heavy rains on car bodies was mainly in terms of faded paint, no corrosion was sighted on car bodies for the period considered (2000-2015)

2. The effect of heavy rains on the underneath of the cars was significant, the corrosion rating was from low to very high.

3. The study noticed that some cars which were manufactured as far back as 2001 had low corrosion sign, this the study concluded that maintenance culture of washing, and the coating used on the underneath of the car must have provided the corrosion resistance against the aggressive muds and dirty water splashing the underneath.

4. The study also concluded that given the advanced coating formulation used by car manufacturers in recent times the corrosion of the underneath of the cars investigated is as a result of global warming triggered heavy rains in Uyo metropolis.

Acknowledgements

The authors of these work are sincerely indebted to all who made their cars available for the study and also provided very useful information to the researchers regarding their cars. In the same vein we wish to sincerely thank the owners of several garages and workshops visited during the course of this research work. Time will fail us to appreciate you by your names individually, however bear with us and accept our heartfelt thanks.

References

[1] Corrosion, E (2015) Why motor car bodies no longer rust, Corrosion Exclusive, volume 1 issue 1, pp24-28.

[2] Cottrell, A. (1980) An Introduction to Metallurgy, 2nd Edition, Arnold publishers, 45p.

[3] Evans, U.R. (1976) The Corrosion and oxidation of metals, 2nd supplementary volume, Edwards Arnold.

[4] Fontana, M.G. (1987) Corrosion Engineering, 3rd Edition, McGraw-Hill Book Company, pp1-4

[5] Aondona Paul Ihom, Ogbonnaya Ekwe Agwu & John Akpan John (2016). The Impact of Vehicular Emissions on Air Quality in Uyo, Nigeria. Mechanics, Materials Science & Engineering Vol.6, doi: 10.13140/RG.2.1.1813.7845.

[6] Ihom, A.P. and Offiong, A. (2014). Zinc-Plated Roofing Sheets and the Effect of Atmospheric Pollution on the Durability of the Sheets, Journal of Multidisciplinary Engineering Science and Technology (JMEST), Germany, ISSN: 31 59-0040, 1(4).

[7] Ihom, A.P. (2014) Environmental Pollution Prevention and Control: The Current Perspective (A Review), Journal of Multidisciplinary Engineering Science and Technology (JMEST), Germany, ISSN: 3159-0040, 1 (5).

[8] Ogbodo, J.N., Ihom, A.P., Moses, S.A. and Denis, U.J. (2015) Corrosion Resistance Characterisation of 90Al-10Cu-4SiC Metal-Matrix Particulate Composite (MMPC) in Some Selected Media, JMEST Vol2 issue8, 2040-2045.

[9] Ryemshak, S.A. and Ihom, A.P. (2015) The Adverse Effects of Flue-Gas Emission and Carbon-soot from combustion of Fossil Fuel Leading to the Phase-out Campaign of Coal-A Review, International Journal of Modern Trends in Engineering and Research,ISSN(Online): 2349-9745, 149-161.