Original Article: Introduction of Consumable Primers in Consumable Tires of Petrochemical Complexes in Hard Rubber Types

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Citation A. Ahmadpour, M. Jalali, **Introduction of Consumable Primers in Consumable Tires of Petrochemical Complexes in Hard Rubber Types** .*EJCMPR* . 2023; 2(5):45-56.

https://doi.org/10.5281/zenodo.8076703

Article info:
Received: 05 February 2023
Accepted: 23 June 2023
Available Online:
ID: EJCMPR-2302-1024
Checked for Plagiarism: Yes
Peer Reviewers Approved by:
Dr. Amir Samimi
Editor who Approved Publication:
Dr. Soroush Zarinabadi

Keywords:
Primer, Rubber, Petrochemical, Hard Rubber.

ABSTRACT

Most of the equipment used in material transportation industries, chemical and non-chemical process industries, and even most military equipment use metal base structures. Corrosion of metals, destruction of metal structure or basic alloy is an obvious thing, the consequences of which may be economic, human, environmental, or in general, the collection of these losses. All these unpleasant consequences stem from several factors, one of the most important and main mechanisms is the phenomenon of corrosion of metal atoms (loss of valence layer electrons of the metal in the presence of oxidizing agents) and their transformation into ions, which are forced to leave the metal structures and entering the surrounding solution or electrolyte. These phenomena lead to the loss of metal mass, which can manifest itself as a decrease in overall thickness (uniform corrosion) and progressive holes in the depth of the metal (pitting corrosion). In general, corrosion is the cause of mechanical failure and the reduction of structural strength is a target process, because its effects cause the equipment to be destroyed and taken out of service against a mechanical stress higher than the threshold of tolerance, followed by economic losses, human casualties and the environment biologically obtained. Historically, researchers and engineers have always faced the phenomenon of corrosion, and depending on the era in which they lived and the level of science and technology at that time, they used one of the methods to protect the surface against corrosion and other destructive mechanisms of the equipment's materials.

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Introduction

Rubbers are miraculous materials with unique applications in different places that we encounter these valuable materials every day without realizing their presence [1-3]. These valuable materials are used in various car parts, toothbrushes, mobile phones, computers, chewing gum, balloons, surgical gloves, bath mats, rubber corks, rubber bands, erasers, road materials, hospital materials, airplanes and spacecraft, fluid transfer hoses and screens. Anti-acid and anti-corrosion can be seen on metal surfaces. Rubbers are one of the strongest and most diverse materials that have countless uses in combination with other materials [4-7].

The oldest traces of rubber were discovered in lignite deposits in Germany in 1924 in a fossil whose lifespan is estimated to be 55-60 million years [8-10]. One of the unique features of these miraculous materials is their elasticity, which remains even after severe processing operations [11-14]. The question that is raised in this context is, what are the materials that we know as rubber in ordinary expression? The shortest answer to this question is that rubber is the most elastic material available that has unique properties such as; They show leakage or sealing, impact and vibration, sound absorption, protection against acids and corrosion and other types of protection [15-18].

There are different types of rubbers and their derivatives that have special properties and uses along with different additives [19]. Elasticity of rubber actually expresses the capacity of a rubber or rubber to withstand large and fully reversible deformations [20]. The larger these deformations are and the quicker and more complete the reversibility to the initial state occurs after removing the action, we say that the studied rubber has more elasticity [21-23]. Elasticity is a special property of polymer materials that are made of long chain-like molecules. In general, for a material to have rubbery properties, it is required that it has long and flexible pseudo-chain molecules in its mass. For every rubber material, there is a stress value called the elastic limit, so that the application of stresses greater than this value causes irreversible deformation in the mass of rubber material [24-30]. In general, the high elasticity of rubber materials is attributed to the presence of millions of long flexible and bendable quasi-chain molecules [31-35]. There are various theories regarding the elasticity of rubber materials. Most of these theories focus on the concept that elastic stress is applied to millions of long chain molecules in different directions and causes temporary deformation of the rubber mass; Because by removing the stress, the mass of rubber returns to its original shape [36].

Natural rubber and its applications from the beginning

Natural rubber or NR is fully described in the second chapter along with other rubbers, which are often synthetic, but in general, NR is actually made from the sap of a tree called Hevea Brasiliensis, which was first grown in Brazil and later in Africa and East Asia. It is discovered and achieved. These trees, which grow in an almost hot but humid climate (about a hundred days of rain throughout the year), are also known as rubber trees [37]. Figure 1 shows a field of trees secreting sap or latex, which is actually the feed for factories producing natural rubber masses. In fact, before the birth of petroleum-based polymer production technologies, NR was the only natural elastic material that was used by humans, and for this reason, the word "Rubber" in scientific texts meant natural rubber or NR [11].

The use and applications of NR had been widespread in the world since its discovery, so that during the World War periods, all the NR productions around the world did not meet the needs. Therefore, the increase in the world's need for NR and its elastic property required scientists to find a substitute material for NR. It should be noted that since the discovery of NR to the creation of today's modern thermoplastics, elastomers have become an integral part of the civilized industrial society due to their diverse and extensive applications. Chemical additives

and their combinations with metals, textiles and plastic materials determine the characteristics and field of application of the final product. The final product may be the main component of a rubber hose resistant to corrosive chemicals, a processed plate attached to the metal surface or wall of an equipment to stop attacks by corrosive substances, a sealing part (leak seal) of an aircraft that has extreme temperature differences. It has to endure a lot, a sound absorbing material to silence the screeching of a hard drive, the main component of a tire for driving on icy roads, airport runways or tropical tracks with high friction temperatures, or in the rocket industry as a material flame retardant abrasive should be used [14].

Figure 1. Rubber tree farm.

Wide range of tires

Many types of polymers and rubbers are available to make the so-called elastomer or polymer compounds. Table 1 lists the types of elastomers along with their abbreviations and brand names in the market.

Table 1. Elastomers used, their abbreviations and trade names in rubber lining operations.

Trade Name	Abbreviation	Elastomer Name	Elastomer name	Row
SMR®, Pale Crepe®, Smoked Sheet®, Ameripol SN®, Narsyn®	NR	Natural rubber	Natural rubber	**1**
SMR®, Pale Crepe®, Smoked Sheet®, Ameripol SN®, Narsyn®	IR	Poly isoprene rubber	Poly isoprene rubber	**2**
Budene®, Taktene®	BR	Polybutadiene rubber	DN poly buta rubber	**3**
Ameripol Synpol®, SBR®, Plioflex®, Stereon®	SBR	Styrene-butadiene rubber	Styrene-Butane DN rubber	**4**
Nordel®, Royalene®, Vistalon®, Buna EP®, Keltan®	EP, EPDM, EPT, EPR	Ethylene propylene rubber	Ethylene-propylene rubber	**5**
Chemigum®, Nipol®, Krynac®, Paracril®, Perbunan N®, BunaN ®	NBR	Acrylonitrile-butadiene rubber (Nitril rubber)	Acrylonitrile-butadian rubber	**6**
Nipol®, Krynac®, Chemigum®	XNBR	Carbocylated Nitril rubber	Carboxylated acrylonitrile-butadiene rubber	**7**
Therban®, Zetpol®	HNBR	Highly saturated Nitril rubber	Highly saturated acrylonitrile-butadiene rubber	**8**
Neoprene®, Baypren®, Butaclor	CR	Poly chloroprene	Poly chloroprene rubber	**9**
Hypalon®	CSM	Chlorosulfonated polyethylene	Sulfonated chlorinated polyethylene	**10**

Adiprene®, Millathane®, Vibrathane®, Vulkolan®, PUR	AU & EU	Polyurethane (polyether or polyester) rubber	Polyether/polyester polyurethane rubber	**11**
Thiokol	PS	Poly sulfides Fluoro rubber	Fluorinated polysulfide rubber	**12**
Butyl®	IIR	Isobutylene Isoprene Rubber	Isobutylene-isoprene rubber	**13**
Kalrez®	FFKM	Perfluoroelastomer	Fluorinated rubber	**14**
Dyneon®, Viton®, Aflas®, Fluorel®	FKM, FEPM	Fluorocarbon	Fluorocarbon	**15**
Silastic®, SILPLUS®, Elastosil®, wacker®	VMQ, PMQ, PVMQ	Silicone Rubber	Silicone rubber	**16**
FSE®, Silastic®, Sylon®	FVMQ	Fluorosilicone	Fluorosilicon	**17**
Gechron®, Hydrin®,	ECO/CO	Epichlorihydrin	Epichlorohydrin	**18**
Vamac®	AEM	Ethylene Acrylic	Ethylene acrylic	**19**
Cyanacryl® , HyTemp® ,Thiacril® ,Thiacryl	ACM	Poly acrylate	Poly acrylate	**20**

Anti-corrosion rubber lining technologies

Although rubbers were originally created for use in engineering industries, industries such as chemical fertilizer production, caustic production, mining and ore crushing, pharmaceutical and papermaking industries have become a demand for rubber. Apart from the elastomeric properties of tires, another important property of this category of materials is resistance to corrosion and wear. To achieve the precise standard and rapid developments in the process industries, rubber specialists have had to develop new types of elastomers and compound formulation technologies. Because the chemical industry deals with the manipulation of various types of corrosive chemicals, it created a need in the field of research and preparation of elastomer manufacturers to create special elastomers as a new class of chemical industry process equipment materials. Research in the field of polymer science and technology has greatly helped elastomer manufacturers [19].

Finally, when the range of elastomers became unlimited, the topic of working with elastomers and their applications in chemical industries became the specialized range of anti-corrosion rubber coating technology. In continuous chemical process industries that cannot replace equipment in a short period of time, prolonging the life of the equipment in the process cycle is essential. For example, the lifetime of a two-inch-thick wall of steel in contact with precise solutions of sulfuric acid is less than 8 months; Because it is eaten according to the general corrosion reaction below [12].

$$H_2SO_4\ (aq) + Fe\ (s) \longrightarrow H_2\ (g) + FeSO_4\ (aq)$$

But if the direct contact of the acid with the body metal is prevented by a protective and anti-acid coating, the life of the equipment will be significantly longer. Considering the entire range of chemical process industries, there is a wide range of corrosive environments. It is important to note that all corrosive and abrasive environments cannot be controlled with elastomeric coatings alone, but among all protective coatings, elastomeric coatings are the overwhelming majority in this field.

One of the important issues that rubber lining affects in the economic dimension of an industrial project is the cost of the main process equipment that is in contact with chemically active and corrosive environments [9]. The combination of mild steel and rubber coating in the manufacture of chemical industry equipment is much cheaper than stainless steel. For example, the cost of building a storage tank with a thickness of 10 mm along with its pipelines using two types of steel is evaluated as follows; The approximate cost per square meter of AISI 316 stainless steel is approximately US$900 and the cost per square meter of rubber coated mild steel is approximately US$550. Therefore, the price difference per square meter is equivalent to 350 US dollars (equivalent to 60% compared to the price per unit surface area of rubberized mild steel tank), which is quite noticeable. Therefore, if the total area of the tank is 7000 square meters, using a tank made of mild steel covered with rubber will save 2.5 million dollars in the cost of tank construction [38].

Introduction to elastomeric materials and compounds in rubber lining

The materials used in the production of rubber coating compounds are very wide in terms of variety. From a technological point of view, you identify and decide on the correct choice of compounds for a particular application based on the specific properties of that compound that the application requires [6]. These characteristics include the compatibility of materials with the composition and type of base polymer and finally their effect on the performance of the final product. In general, the raw materials required for the production of rubber coating compounds are grouped as follows:

1- Rubber (Natural and synthetic);

2- Process oils;

3- Activators;

4- Softeners;

5- Baking agents;

6- Accelerator;

7- Antioxidants;

8- Fillers;

9- Solvents;

10- Adhesives/Bonding agents.

History and Introduction to NR

Natural rubber, which is known as Indian rubber, latex, Amazonian rubber, cautho, or Caoutchouc rubber, is composed of an organic compound polymer of isoprene or 3-methyl-1 and 3-butadiene (Figure 2) along with some impurities and water. Its natural type, which is extracted from the rubber tree, is also called elastomer. Although the primary source of NR was the native tree of the American continent, Hevea Brasiliensis, but due to the leaf rust pest of this tree, NR production has not been widely developed in this continent. East Asian countries are among the pioneers in the production of this valuable product in the world. Thailand, Malaysia and Indonesia are among the biggest producers of NR in the world. Because the growth and production conditions of the rubber tree require a climatic condition with an average of one hundred days of rain per year [1]. These trees produce a viscous, milky colloid called latex, which is extracted by making cuts in the trunk and through a process called "Tapping." The latex is then refined into rubber, which is ready for commercial processing. Finally, the latex obtained after the coagulation and purification operations is ready for further processing with commercial purposes [25]. The natural rubber obtained from this latex in most useful forms has a high stretch ratio, high flexibility and is highly waterproof.

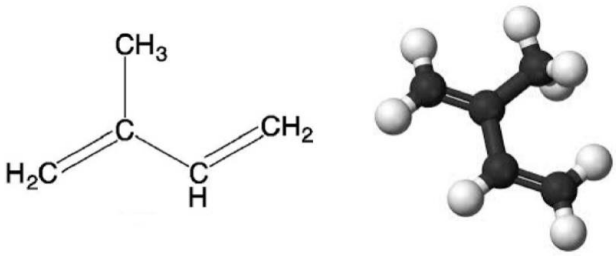

Figure 2. Molecular structure and ball-rod model of isoprene or 2-Methyl-1,3-Butadiene.

Definition of Robert Lining

Rubber lining or rubber coating, which is also known as rubber lining and rubber work, is a method of protecting surfaces against corrosion in which the entire surface is covered by a layer of rubber with a thickness of 3 to 30 mm.

Application cases of rubber lining

The most important phenomenon that necessitated the need for rubber materials in various industries is the phenomenon of corrosion, which is shown in its effects on some equipment, as shown in figure 3. Coating with rubber sheets is usually used to protect the internal surfaces of tanks, pipes and parts with the following uses in the oil, gas, refining, petrochemical, drilling, mining and also factories that produce or transport corrosive substances:

- Rubber lining storage tanks for acids such as hydrochloric acid, brine or sodium hypochlorite, dilute sulfuric acid, phosphoric acid and nitric acid and storage tanks for alkalis such as caustic soda or caustic soda.
- As an impermeable membrane layer in anti-acid and base tile and brickwork systems in acid and base neutralization tanks or sumps.
- Rubber lining of tanks for transporting corrosive substances.
- Rubber Lining tanks of industrial water treatment units in power plants and factories that are permanent users of water and need to produce demineralized water, such as tanks containing mixed resin beds, anion and cation tanks, Anionic & Cationic Tanks, resin back wash tanks.
- Rubber lining inside electrolysis cells in chloralkali plants.
- Rubber lining of pipes and valves for transferring salt water, sea water and corrosive substances.
- Abrasion and corrosion resistant layer in pulp tanks, shots, and slurry passage pipes, etc.

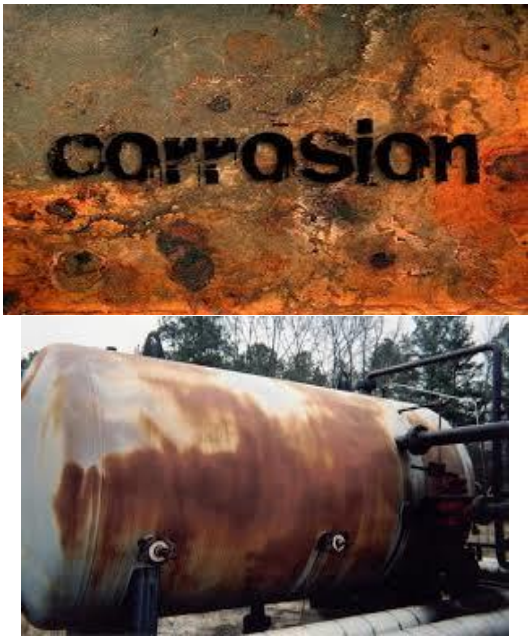

Figure 3. Corrosion of equipment surfaces.

Types of rubber lining in terms of final hardness

Rubber coatings are divided into two types, soft and hard, in terms of final hardness. The tires whose hardness falls within the Shore A hardness range are called soft tires and the tires whose hardness falls within the Shore D hardness range are called hard tires. Of course, tires with a hardness between the two mentioned categories are rarely produced, which are called semi-hard rubber. The final hardness of the rubber is not usually considered as a characteristic for the selection of rubber linings, but the final hardness of the rubber can cause limitations in the selection. For example, hard tires should not be used for transport tanks; Because these tanks are constantly exposed to mechanical stress and soft rubbers are a more suitable choice due to their high flexibility [19].

Types of rubber lining in terms of execution method

In terms of the application method, rubber coating is divided into two categories: rubber lining in the workshop and rubber lining on the site (customer site).

A- Rubber lining by warm method

Some rubber coverings are installed raw in the tank/part and after application, in order to achieve chemical resistance and desirable mechanical properties, they must be vulcanized, which is done either by cooking under high pressure and heat in an autoclave. Of course, curing with steam, hot water or hot air is also possible on the site or the rubber manufacturing company designs the rubber formulation in such a way that the rubber coating is vulcanized in a longer period of time but at ambient temperature and pressure, and in this way it can be avoid cooking.

B- Rubber lining by cold method

Another group of rubber liners have already been vulcanized at the rubber manufacturing plant, so they do not need to be cured after being installed in the tank, and they can be used immediately after installation. Of course, pre-vulcanized tires can be used in both the workshop and the site, but depending on the final hardness required and the type of polymer base selected, sometimes they cannot be used on the site and must be vulcanized in an autoclave. Usually, the final quality of hot rubber lining is better than that of cold lining, because in hot rubber lining, first of all, due to the low hardness of the raw rubber, the formability and flexibility of the sheet, and the compatibility with the complex shapes of the tank (for example, the execution details on the nozzles) are much better than rubber. It is pre-vulcanized, secondly, the sheets of raw rubber are connected in the place of the overlaps with an adhesive of the base rubber itself, and during the vulcanization operation, a polymer chain is formed in the place of the overlaps, and finally a strong chemical bond is formed, but two-component adhesive system is usually used in cold rubber lining because the rubber is pre-vulcanized. Therefore, a physical bonding is created in place of the overlaps. Although the special adhesives of cold rubber liners also have very high strength and chemical resistance, but due to the integration of the overlaps in the hot method, the final quality of the hot method is more favorable.

1 Formulation of rubber lining adhesives

In order to achieve a strong connection of rubber coating to metal and plastic substrates, a customized adhesive system with strong, reliable and long-lasting adhesion is needed. For this purpose, adhesives with different formulations have been created to meet this demand by many rubber lining companies, which are mostly proprietary.

Abrasion-resistant rubber covering adhesive for grout lines

In order to categorize the chemical and technical information related to this type of glue, which is used to stick rubber coatings on the surfaces of metal equipment in contact with slurry flows, table 2 (qualitative and quantitative chemical analysis information) and table 3 (technical information) was set. It is noteworthy that the mixture of table 2 is dissolved in toluene with a ratio of 75:25 and sticks to the metal as a

secondary layer until finally the rubber coating is flat on it.

Table 2. Chemical information of the glue required for the connection of the rubber coating resistant to the wear of the grout.

Name/Symbol	kg	Additive	Row
RMA 1X	10	Natural rubber or NR grade 1	**1**
Zinc Oxide	0.5	ZnO	**2**
Stearic acid	0.1	Stearic acid	**3**
Paraffin wax	0.3	Paraffin wax	**4**
Naphtenic oil	0.6	Naphthenic oil	**5**
SRF black	7.4	Carbon black grade Semi-reinforced furnace	**6**
HBS	0.12	Cyclohexyl Benzthiazyl Sulphenamide curing accelerator	**7**
Sulfur	0.23	Sulfur	**8**
Salicylic acid	0.03	Salicylic acid	**9**
PBN	0.1	Pheny-alpha-tert butyl-nitrobenzene antioxidant	**10**
Total	20.8	Total amount	**11**

Table 3. Technical information of the adhesive required for the connection of the rubber coating resistant to the wear of the grout.

Parameter value	Parameter	Row
1.2	Special Weight	1
30	Wallace's malleability	2
MS 1+3 at 120°C, 8mi	Mooney scorch time	3
175 Kg cm^{-2}	Tensile strength	4
550%	Final stretch	5
70Kg cm^{-2}	300% tensile modulus	6
55 ^{0}A	Shore hardness	7

Chemosil adhesives

Chemosil adhesive is one of the most important and resistant adhesives used to connect rubber to metal in various chemical, petrochemical, oil, etc. industries. In addition to connecting elastomers to metal and alloys, this type of glue is also used to connect tires to polymer and plastic substrates that have a polar base. Chemosil glue can be used alone or in cases where the process conditions are more severe, together with a suitable primer layer.

Database of rubber coatings

Information about rubber coatings used in the petrochemical industry is as described in the following table:

Table 4. Database of rubber lining in petrochemical companies of special region of Mahshahr and Asalouye.

Top coat		Middle coat		Primer		Type of cooking	Rubber		Petrochemical
[A]Kg	Type	[A]Kg	Type	[A]Kg	Type		[A]m2	Type	
	Cement SX		PA231		PA211	Steam		Rubber CINA BOUNIT 2194 G	**Fanavaran**
								EPDM	**Fanavaran**
								VITON	**Fanavaran**
								KALREZ 6375/4079	**Fanavaran**
								NITRILLE	**Fanavaran**
								FFKM	**Fanavaran**
								25% GLASS LOADED TEFLON	**Fanavaran**
								NOVAPRESS MULTI GASKET NOVAFLON	**Fanavaran**
								NBR	**Fanavaran**
								PTFE	**Fanavaran**
								GYLON STYLE 3500	**Fanavaran**
					CHEMOSIL 211			EBONIT SHEET MH EW	**Zagros**
								Hard RUBBER GRAPHILIC EBONITE	**Zagros**
								Hard RUBBER CHEMONITE 181	**Zagros**
								Hard RUBBER CHEMONITE 31	**Zagros**

		J						Hard RUBBER	**Zagros**
	POLYAMIDE MODIFIED HIGH BUILT EPOXY-125 MICRON DFT				INORGANIC COAT SILICATE 75 MICRON DFT				**Ariasasol**
	PLASTIC LINING								**Ariasasol**
	FINISHED EPOXY 150 MICRON				PHENOLIC EPOXY 150 MICRON				**Ariasasol**
	TEFLON LINING								**Ariasasol**
	ADHESIVE CO 94,2+AKODS				TUMBURI NR PRIMER CO94,1	Steam	100	EPDM	**Boushehr**
							50	NBR	**Fajr**
							20	BUTYL	**Fajr**
							50	EPDM	**Fajr**
							50	Hypalon	**Fajr**
							25000	Bromo Buthyl Rubber	**Arvand**
								NR	**Arvand**
								EBONITE	**Karoun**

Conclusion

The use of primer significantly increases the environmental resistance of the final product. This glue is used to connect tires to various car parts, to connect to cement factory rollers and rubber lining of various tanks. This glue has found an important place in the market of rubber lining glues due to its various applications. One of the most important factors that should be taken into account when working with Chemosil glue is the cleaning of the surfaces, which must be done at a high level so that the finished product has a good quality in terms of strength and resistance. Usually, before gluing, oils and greases are removed by degreasing methods with solvents or alkaline solutions.

References

[1] M. Bagheri Sadr, A. Bozorgian, J. Chem. Rev., **2021**, 3, 66-82. [Crossref], [Google Scholar], [Publisher]
[2] A. Bozorgian, J. Chem. Rev., **2021**, 3, 50-65. [Crossref], [Google Scholar], [Publisher]
[3] A. Haghighi Asl, A. Ahmadpour, N. Fallah, J. Model. Eng., **2018**, 16, 295-307. [Crossref], [Google Scholar], [Publisher]
[4] A. Bozorgian, J. Basic Appl. Sci. Res., **2012**, 12, 12923-12929. [Google Scholar], [Publisher]
[5] A. Samimi, S. Zarinabadi, A. Bozorgian, Int. J. New Chem., **2021**, 8, 149-163. [Crossref], [Google Scholar], [Publisher]
[6] A. Bozorgian, A. Samimi, Int. J. New Chem., **2021**, 8, 41-58. [Crossref], [Google Scholar], [Publisher]

[7]A. Haghighi Asl, A. Ahmadpour, N. Fallah, Appl. Chem., **2017**, 12, 253-286. [Crossref], [Google Scholar], [Publisher]
[8]A. Bozorgian, M. Ghazinezhad, J. Biochem. Technol., **2018**, 2, 149-153. [Google Scholar], [Publisher]
[9]A. Bozorgian, J. Eng. Ind. Res., **2021**, 2, 90-94. [Crossref], [Google Scholar], [Publisher]
[10] S. Karami, M. Javan Nikkhah, K.B. otouhifar, V. Rahjoo, A. Ahmadpour, Iran. J. Plant Prot. Sci., **2020**, 51, 129-146. [Crossref], [Google Scholar], [Publisher]
[11] A. Ahmadpour, A.H. Asl, N. Fallah, Part. Sci. Technol., **2018**, 36, 791-798. [Crossref], [Google Scholar], [Publisher]
[12] A. Ahmadpour, Adv. Environ. Technol., **2015**, 1, 121-127. [Crossref], [Google Scholar], [Publisher]
[13] A. Bozorgian, J. Eng. Ind. Res., **2021**, 2, 194-201. [Crossref], [Google Scholar], [Publisher]
[14] A. Haghighi Asl, A. Ahmadpour, N. Fallah, Adv. Environ. Technol., **2016**, 2, 153-168. [Crossref], [Google Scholar], [Publisher]
[15] A. Bozorgian, J. Eng. Ind. Res., **2021**, 2, 166-177. [Crossref], [Google Scholar], [Publisher]
[16] N. Norouzi, A. Bozorgian, M.A. Dehghani, J. Environ. Assess. Policy Manag., **2022**, 22, 2250001. [Crossref], [Google Scholar], [Publisher]
[17] M. Kalbasi, A. Hedayati, A. Ahmadpour, World Appl. Sci. J., **2010**, 11, 228-234. [Google Scholar], [Publisher]
[18] A. Bozorgian, J. Chem. Rev., **2021**, 3, 109-120. [Crossref], [Google Scholar], [Publisher]
[19] S.E. Mousavi, A. Bozorgian, Int. J. New Chem., **2020**, 7, 195-219. [Crossref], [Google Scholar], [Publisher]
[20] A. Bozorgian, Z. Arab Aboosadi, A. Mohammadi, B. Honarvar, A. Azimi, Eurasian Chem. Commun., **2020**, 2, 420-426. [Crossref], [Google Scholar], [Publisher]
[21] A. Ahmadpour, A. Bozorgian, Eurasian J. Sci. Technol., **2021**, 1, 28-39. [Crossref], [Google Scholar], [Publisher]
[22] A. Bozorgian, N.M. Nasab, A. Memari, interaction, **2011**, 1, 4. [Crossref], [Google Scholar], [Publisher]
[23] A. Bozorgian, J. Eng. Ind. Res., **2020**, 1, 99-110. [Crossref], [Google Scholar], [Publisher]
[24] A. Surendar, A. Bozorgian, A. Maseleno, L.K. Ilyashenko, M. Najafi, Inorg. Chem. Commun., **2018**, 96, 206-210. [Crossref], [Google Scholar], [Publisher]
[25] J. Mashhadizadeh, A. Bozorgian, A. Azimi, Eurasian Chem. Commun., **2020**, 2, 536-547. [Crossref], [Google Scholar], [Publisher]
[26] N. Norouzi, A.G. Ebadi, A. Bozorgian, E. Vessally, S.J. Hoseyni, Iran. J. Chem. Chem. Eng., **2021**, 40, 1909-1930. [Google Scholar], [Publisher]
[27] B. Ganavati, V.A. Kukareko, L.S. Tsybul'Skaya, S.S. Perevoznikov, Phys. Metals Metallogr., **2014**, 115, 1037-1045. [Crossref], [Publisher]
[28] A. Ahmadpour, A. Bozorgian, A. Eslamimanesh, A.H. Mohammadi, Desalination Water Treat., **2022**, 249, 297-308. [Crossref], [Google Scholar]
[29] A. Bozorgian, Adv. J. Chem. B, **2020**, 2, 91-101. [Crossref], [Google Scholar], [Publisher]
[30] M. Ghazinezha, A. Bozorgian, P. Gholami Dastnaei, Int. J. New Chem., **2022**, 9, 623-646. [Crossref], [Google Scholar], [Publisher]
[31] A. Johnson, Eurasian Journal of Chemical, Medicinal and Petroleum Research, **2023**, 2, 1-9. [Google Scholar], [Publisher]
[32] S Zarinabadi, A Samimi, International Congress of Chemical and Process Engineering, CHISA, **2012** [Google Scholar], [Publisher]
[33] A Samimi, American Journal of Research Communication (AJRC), **2013** [Google Scholar], [Publisher]

[34] A Hedayati, B Almasinia, A Samimi, **2014** 5, 20-29 [Google Scholar]
[35] F Delborty, Eurasian Journal of Chemical, Medicinal and Petroleum Research, 1(3), **2022**, 100-109 [Google Scholar], [Publisher], [Crossref],
[36] F Safari, H Safari, Eurasian Journal of Chemical, Medicinal and Petroleum Research, **2022**, 1 (2), 150-154 [Google Scholar], [Publisher]
[37] F. Rebout, Eurasian Journal of Chemical, Medicinal and Petroleum Research, **2022**, 1, 20-32. [Google Scholar], [Publisher], [Crossref]
[38] F. Rebout, Eurasian Journal of Chemical, Medicinal and Petroleum Research, **2022**, 1, 58-63. [Google Scholar], [Publisher]