Eco- friendly , Low-Cost Adsorbents used for the Removal of Alizarin Red - S dye - A Review

THARANI. S

(17PCH022)

Thesis Submitted to

Avinashilingam Institute for Home Science and Higher Education for Women

Coimbatore- 641 043.

In Partial Fulfilment of the Requirements for the Degree Of

MASTER OF SCIENCE IN CHEMISTRY

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Signature of the Supervisor

16/4/19

Signature of the Head of the Department

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THARANI. S

CONTENTS

INTRODUCTION

INTRODUCTION

POLLUTION:

Pollution is the introduction of contaminants into the natural environment that cause adverse change. Pollution can take the form of chemical substances or energy, such as noise, heat, or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants.

TYPES OF POLLUTION:

- Air pollution
- Water pollution
- Soil pollution
- Radioactive pollution
- Biological pollution

AIR POLLUTION:

Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth's atmosphere. It may cause diesease, allergies, or death of humans.

Human activity and natural processes, both generate air pollution.

Air pollutant is a substance in the air that can have adverse effects on humans and the eco system. Pollutants are classified as Primary pollutants and Secondary pollutants.

Air pollution can be minimized by filtration of industrial chemicals, reducing the use of petroleum related automobiles.

PRIMARY POLLUTANTS:

- They are usually produced from a process, such as ashes from a volcanic eruption.
- Other Examples: Carbon dioxide gas from motor vehicle, Sulphur dioxide released from industries

SECONDARY POLLUTANTS:

- They are not emitted directly.
- Rather, they form in the air when primary pollutants react or interact.
- Ground level ozone is a prominent example of a secondary pollutant.

Before flue-gas desulfurization was installed, the emission from the power plant contained excessive amounts of sulfur dioxide.

CAUSES OF AIR POLLUTION:

1) Emissions from industrial plants and manufacturing activities.

2) Combustion from fossil fuels.

3) Farming chemicals and household products.

4) Natural causes of air pollution

Industrial plants, factories and power plants release high amounts of organic compounds, chemicals, particulate matter and carbon monoxide into the air. Industrial plants that refine petroleum, manufacture cement, produce metal, process plastics, manufacture chemical products release lot of foreign harmful materials into the air.

Petroleum refineries emit high level of hydrocarbon into the air. Conventional power plants that combust fossil fuels to produce energy emits hazardous gases such as oxides of nitrogen, carbon monoxide and hydrocarbon into the air.

Natural event that lead to air pollution include volcanic eruption, whirlwinds, forest fires, and gaseous releases from decaying plants and animals or radioactive decay of rocks.

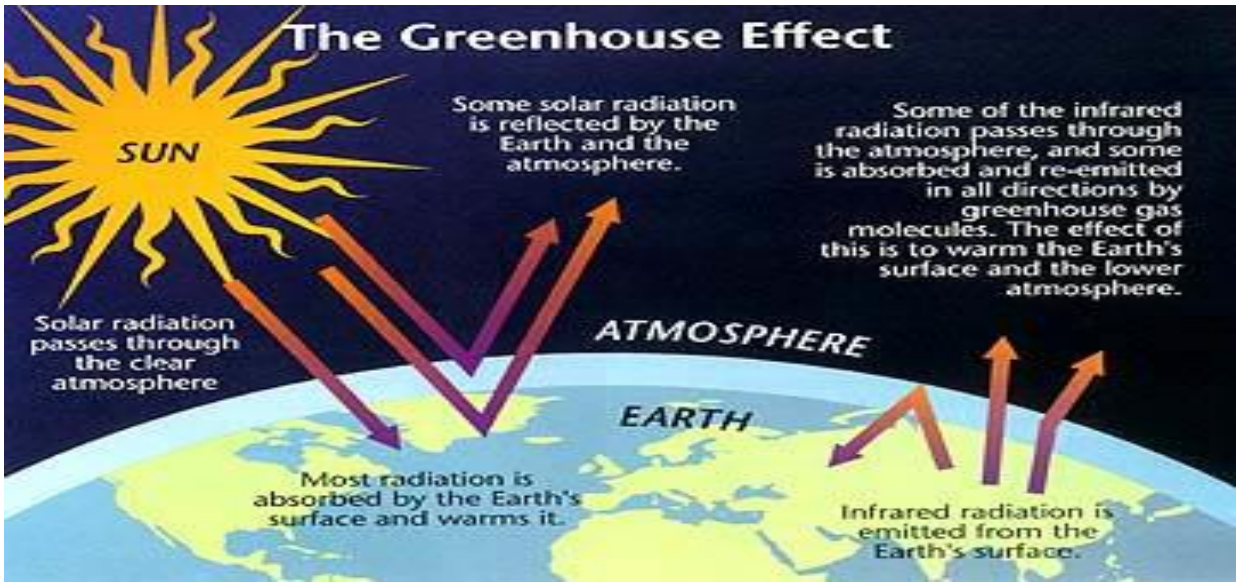
GREEN HOUSE EFFECT

The green house effect is a natural process that warms the earth's surface. When the sun's energy reaches the earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re- radiated by greenhouse gases.

The absorbed energy warms the atmosphere and the surface of the earth. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some critical chemicals like chlorofluorocarbon.

SOURCES OF GREEN HOUSE GASES

There are 2 ways, that greenhouse gas emissions enter our atmosphere. One of them is through human activities. The main human sources of greenhouse gas emissions are fossil fuel use, deforestation, intensive livestock farming, use of



synthetic fertilizers, and industrial processes. The other is through natural processes like animal and plant respiration.

WATER POLLUTION:

- ✓ Water pollution is the contamination of water bodies (*Lakes, rivers, oceans, aquifers and ground water).*
- ✓ This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds.
- ✓ Water pollution is a major global problem and sources of surfaces water pollution are generally grouped into categories based on their origin.

POINT SOURCE WATER POLLUTION:

1) Point source water pollution refers to contaminants that enter a waterway from a single, identifiable source, such as pipe, ditches.

Example: Discharges from a sewage treatmentplant, a factory or a city storm drain.

NON-POINT SOURCES:

2) It refers to diffuse contamination that does not originate from a single discrete sources.

Example: Leaching out of nitrogen compounds from fertilized agricultural lands.

CAUSES OF WATER POLLUTION:

1) Sewage and Waste water

2) Industrial waste

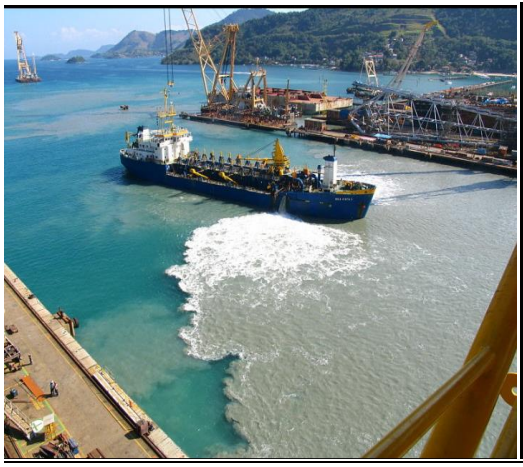
3) Oil pollution

4) Acid rain

5) Global warming

MARINE POLLUTION:

- Marine pollution occurs when harmful or potentially harmful effects result from the entry into the ocean of chemicals, particles, industrial, agricultural and residential waste or the spread of invasive organisms.
- 80% of marine pollution comes from land.
- Pollutants enter rivers and the sea directly from urban sewages and industrial waste discharges, sometimes in the form of hazardous and toxic wastes.



- Ships can pollute waterways and oceans in many ways. Oil spills can have devastating effects. Polycyclic aromatic hydrocarbon (PAHs) found in crude oil, are very difficult to clean up. Discharge of cargo residues from bulk carriers can pollute ports, waterways, and oceans. The oceans are normally a natural carbon

sink, absorbing carbon dioxide from the atmosphere. Because the levels of atmosperic carbon dioxide are increasing, the ocean become more acidic.

Ocean and coastal ecosystems play an important role in the global carbon cycle. It have removed about 25% of the carbon dioxide emitted by human activities.

SOIL POLLUTION:

Soil pollution as part of land degradation is caused by the presence of xenobiotic chemicals or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals or improper disposal of waste.

.CAUSES FOR SOIL POLLUTION:

1) Industrial waste dumping in land

2) Deforestation

3) Excessive use of fertilizers and pesticides

4) Garbage pollution

EFFECTS OF SOIL POLLUTION:

Climate change:

Deforestation causes a change in the rain cycle and this is a contributing factor to global warming and loss of ecosystem.

Loss of soil fertility:

With the rapid growth of human population, we need food form all by using chemical fertilizers and pesticides to increase the crop production. Chemicals used on soils reduce soil fertility and soil quality.

RADIOACTIVE POLLUTION:

The term radiation can refer to a wide variety of forms of energy moving around as waves or particles. It can mean X- rays or it can mean microwaves. It can also refer to infrared light and even visible light. But when we say radioactive pollution, we are being more specific. Radioactive pollution refers to the release of ionising radiation into the environment as a result of human activity.

Ionizing radiation is the form of radiation that has a short wavelength and a high frequency. In short, it's the form of radiation that's commonly thought of as being high energy and thus harmful to living things. Ionizing radiation includes x- rays and gamma rays.

TYPES OF RADIOACTIVE POLLUTION

Radiation are classified into two types, they are:

- Non- ionizing radiations
- Ionizing radiations

NON- IONIZING RADIATION

Electromagnetic waves of longer wavelength which are near ultraviolet rays to radio waves are known as non- ionizing radiation. These radiations have enough amount of energy to excite molecules and atoms of the medium via which they travel. They make atoms to vibrate faster and but does not have enough amount of energy to ionize them.

IONIZING RADIATION

These radiations are electromagnetic radiations that have high energy like gamma rays, x- rays and short wavelength ultraviolet radiations. These rays of energy like alpha, beta, and gamma are generated in radioactive decay, have the ability to ionize molecules and atoms via which they travel. They also have ability to change molecules and atoms into charged ions. Radioactive decay is a process from which alpha, beta and gamma radiations are generated.

CAUSES OF RADIOACTIVE POLLUTION

Radioactive pollution is caused when radioactive matter is allowed to contaminate the environment. There are several main ways in which this can happen.

A key cause of radioactive pollution is breaches at nuclear power plants, which can result in leakages of radioactive matter into the environment. As nuclear energy becomes a big alternative fossil fuels, this risk increases.

Another cause is chemical spills. Radioactive chemicals can, whether due to improper transport or to containers breaking, spill out into the atmosphere and onto the ground.

Another cause of radioactive pollution is when scientific experiments involving radiation are not conducted with the proper care. A famous case is the scientist Marie Curie, whose studies into the curative effects of radiation actually caused her to fall ill from radiation poisoning. Nevertheless, her discoveries helped us to make great strides towards treating and curing cancer. Radioactive material must be handled with great care.

EFFECTS OF RADIOACTIVE POLLUTION

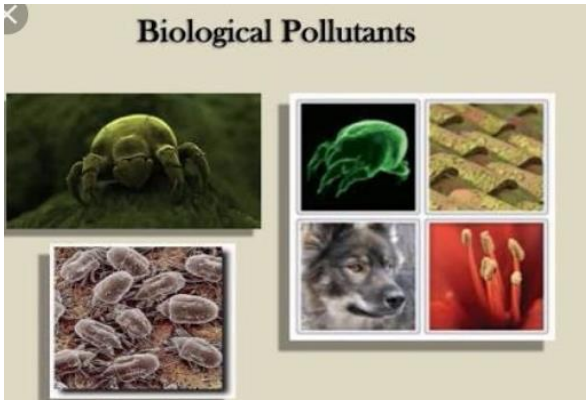
Radiation alters and destroys cells in living organisms. Whether an organism is a plant or an animal (including a human), radiation can result in illness or death.

Radioactive pollution can cause genetic mutations in living organisms and in their descendants. If the animal is exposed to radioactive pollution, for example, it may give birth to babies that have severe congenital defects. These mutations can also cause cancer, sometimes several years in the future, as well as conditions such as infertility. Radioactive burns can cause blistering, reddening, pain and damage to skin tissue.

Damage to the soil and plants is another key effect of radioactive pollution. Radioactive pollution can leave soil infertile and unfit for crops for several decades. It can leave the air unsafe to breath too.

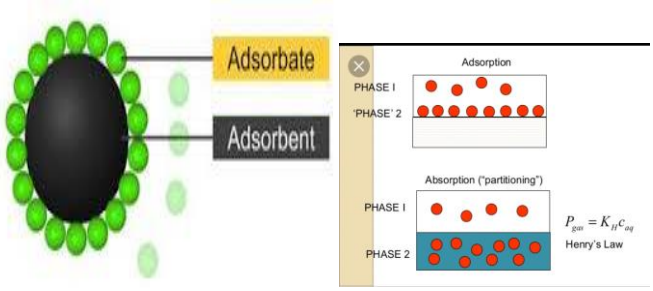
BIOLOGICAL POLLUTION

Disturbance of the ecological balance by the accidental or deliberate introduction of the foreign organism, animal or plant species in to the environment. Bio pollution cause decline in naturalness of nature conservation areas. **Amany yousself *e*t al.,(2008)**



ADSORPTION

- The surface of a solid has a tendency to attract and to retain molecules of other species with which such surfaces comes in contact.
- This phenomenon of surface is called adsorption.
- It is a technical term coined to denote the taking up of gas, vapour or liquid by a surface or interface.



ADSORBATE

- The substance which gets adsorbed on any surface is called adsorbate.

Example: If the gas gets adsorbed on to the surface of a solid, then the gas is termed as adsorbate.

ADSORBENT

- The substance on the surface of which adsorption takes place is called adsorbent. The concentration of the adsorbed molecule always found to be greater in the immediate vicinity of the surface (Adsorbent) than in the free phase (Adsorbate).
- Adsorption-surface phenomenon. Equilibrium easily attained in very short time. Absorption-bulk phenomenon. Equilibrium takes place slowly.

TYPES OF ADSORPTION

Depending upon the nature of force existing between adsorbate molecule and adsorbant, four types of adsorption can be distinguised,

- Physical adsorption
- Chemical adsorption
- Exchange adsorption or ion exchange
- Specific adsorption

Physisorption: Results from action of weak vander Waals forces, interactions between the dipole moment of adsorbate and adsorbent molecule. It is non-specific

Chemisorption : Involves strong adsorbent –adsorbate interactions resulting in change in the chemical form of the adsorbate. Gas molecule or atom held to the solid surface by chemical bond.

Ion exchange: Involves electrostatic attachment of ionic species to sites of opposite charge at the surface of an adsorbent. In this adsorption, the characteristic interactions are ion-ion and ion-dipole type.

Specific adsorption: Attachment of adsorbate molecule at functional groups on an adsorbent surface can also result from specific interactions, which do not result in adsorbate transformation.

Interactions exhibit a range of lower binding energies associated with physical adsorption to the higher energies involved in chemisorptions.

TYPES OF ADSORBENT:

Conventional adsorbent

- Activated carbon
- Silica gel
- Activated alumina
- Clay minerals etc.,

Non-conventional adsorbent

- Adsorbent from industrial wastes
- Adsorbent from coal
- Adsorbent from bio-resources
- Commercially available activated carbon etc..

REVIEW OF LITERATURE

REVIEW OF LITERATURE

One can utilize resources of inexpensive waste and little used materials among various ways of treating industrial effluents containing dyes. Human are dependent upon ecosystem services such as air, water and food for survival. Most of the pollutions are due to increase in population, growth of industries, urbanization, lack of environment awareness and use of chemical fertilizers instead of organic manures. Dyes have harmful effects on environment and human health. Most of the dyes are completely resistant to biodegradable process. Coloured waste water cannot be discharged without adequate treatment, due to toxic nature of dyes to plants and microorganisms. **(Josep Egli., 2007)**

Waste water Treatment

Various techniques have been employed for the removal of dyes from waste water. They involve the combination of physical, chemical and biological methods such as chemical coagulation /flocculation, advanced oxidation process, chemical precipitation, ion- exchange, reverse osmosis, sedimentation etc., may be efficient for the removal of dyes from waste water. **(Kumar and Tamilarasan., 2012)**

There are four types of waste water treatment:

- Preliminary treatment process
- Primary treatment process
- Secondary treatment process
- Tertiary treatment process

Preliminary treatment process

- The coarse and readily settle able inorganic solids with the size range of more than 0.01mm, such as sand and grit particles are removed by preliminary treatment and this was carried out using screen and grit chambers.**(Shon *et al* .,2006)**

- Screening process used to remove certain materials like piece of woods, plastic, paper, floatry debris, rags etc. present in the waste water. **(Sharma and kaur.,1998)**
- By using grit chambers, the heavy inorganic materials like sand, ash and others can be removed. By the method of floatation skimming tanks, grease and oily substance can be removed. **(Satyanarayana., 2006)**

Primary treatment process

In this treatment most of the settleable solids are separated or removed from the waste water by physical processes of sedimentation and flotation.

They are three ways :

- Sedimentation
- Flotation
- Filtration

Sedimentation

It is a physical phenomenon relating to the settling of solids by gravity. Sedimentation for solid separation is a very common process and is routinely employed at the beginning and end of waste water treatment operation.

Flotation

Dissolved air flotation involves the dissolution of air in waste water by pressurizing it in a pressure vessel. When the air saturated waste water is released to the flotation tank, the sudden decrease in pressure causes the air to come out of the solution as micro-bubbles which will attach themselves to solid particles in the waste water and make them floa. **(Carty *et al.*,1997)**

Filtration

Waste water is passed through a filter medium to separate solids. An example would be the use of sand filters to further remove entrained solids from treated waste water.

Secondary treatment process

The process consists of removing or reducing contaminants that are left in waste water from primary treatment process.

They are two ways :

- Chlorination
- Coagulation

Chlorination

It is commonly used chemical process. Chlorine is a strong oxidizing chemical used to kill bacteria and slow down the rate of decomposition of the waste water. **(Shon *et al*.,2006)**

Coagulation

Treatment of waste water with coagulant removes colloidal and coarse dispersed impurities is coagulation. **(Kaur., 2005)**

Oxidation process

Oxidation process is a one of the method of wastewater treatment by using oxidizing agents. Two methods such as UV assisted oxidation and chemical oxidation using chlorine, hydrogen peroxide, fenton's regent, ozone and potassium permanganate are used for treating the effluents. Hydrogen peroxide is used for the decolourisation of dyes, which has strong oxidizing properties and it is a powerful bleaching agent. Chlorine is obtained from calcium hypochlorite and sodium hypochlorite, which is a strong oxidizing agent. Textile industry effluent containing reactive dyes, remazol carbon, remazol gold yellow was decolourised using fenton's oxidation**. (Gupta and suhas, 2009)**

Ozonation process

Ozonation process has been found to be very effective for the removal of dyes from textile effluents. Ozonation can be used to remove the colour

completely and chemical oxygen demand to an extent this was suggested by many authors which is sufficient for the reuse of water**. (Wu *et al* ., 2008)**

Tertiary treatment process

Tertiary treatment is the final treatment meant for polishing the effluents from the secondary treatment process**.**

Electrochemical process

Electrochemical process is a tertiary treatment used to remove colour. In this process decolourisation can be achieved either by electro oxidation with non -soluble anodes or by electro-coagulation using consumable materials. The main drawbacks of this process are high electricity cost, sludge production and causes pollution due to indirect oxidation**. (Gupta and Suhas., 2009)**

Reverse osmosis

It is a filtration method where the demineralized water is forced through a semipermeable membrane at high pressure which removes large molecules and ions from the solution. The membrane is better at rejecting salts, non ionized weak acids, bases and smaller organic molecules**. (Kaur., 2005)**

Ion exchange

It is a reversible chemical reaction where in an ion from solution is exchanged for a similarly charged ion attached to an immobile solid particle. These solid ion exchange particles are either naturally occurring inorganic zeolites or synthetically produced organic resins**.**The largest application of ion exchange process of drinking water treatment is in the area of softening and the removal of hardness producing salts. **(Wu *et al*.,2008)**

Adsorption

The term adsorption refers to the accumulation of a substance at the interface between two phases (liquid-solid interface or gas-solid interface).

The substance that accumulates at the interface is called adsorbate and the solid on which adsorption occurs is adsorbent.

Hence adsorption is defined as " The concentration of substance at the interface between two immiscible phase like solid-liquid, solid-gas, liquid-liquid or liquid-solid". Adsorption is a surface phenomenon, the larger the surface area, greater will be the adsorption.

Adsorption is one of the efficient method to remove dyes from effluents. Activated carbon or charcoal is considered as a most suitable adsorbing media for such purpose. Hydrocarbons, organic acids, esters, ketone and heavy metals get readily adsorbed on activated carbon. **(Rajeshkannan *et al*., 2009)**

COMMERCIAL ADSORBENTS

A number of materials have been investigated as adsorbent in waste water treatment. Some of the important ones included , activated alumina, zeolites and activated carbon etc.

Activated carbon

Dynamic removal of Alizarin Red S by activated carbon Norit GCA830 has been experimentally studied in fixed bed column. Both Freundlich and Langmuir models were found to fit the adsorption data well, but the Langmuir model is better. **(Ali Benhmidene *et al*., 2017)**

The activated charcoal was used for the removal of Alizarin Red dye from aqueous solution. The adsorption of the dye molecules increased as increased the adsorption time. The experimental data was best filled to Langmuir isotherm which illustrated the adsorption of dye on the surface of charcoal was monolayer adsorption. **(Mohammad Ishaq *et al*.,2014)**

Alumina

Alumina was used as an adsorbent for removal of Alizarin Red- S from aqueous solution. Optimum conditions for the removal of Alizarin Red with

alumina obtained using 0.65g of adsorbent dose, dye concentration (25ppm) at 30°C. **(Rabia Rehman *et al*., 2011)**

An alumina-carbon composite was used for the removal of Alizarin Red-S dye. The percentage removal of dye increases with increases in adsorbent dosage and decreases with increase in initial dye concentration. The adsorption studies were well fitted to Tempkin adsorption isotherm. **(Pranay A Raut *et al*., 2013)**

Calcium hydroxide, a low-cost adsorbent used for the removal of Alizarin Red-S dye by varying the parameters such as pH, concentration, dose of adsorbent, time and temperature . The kinetic studies indicate that the adsorption followed pseudo-second-order rate equation.
(Thimmasandra Narayan Ramesh *et al*., 2016)

LOW COST ADSORBENT

Materials which are locally and abundantly available such as agricultural wastes and industrial by- products can be utilized as low cost adsorbent. These materials can be converted into adsorbents for waste water treatment would help to reduce the cost of waste disposal and provide an alternative to commercial activated carbon**. (Kurniawan *et al*., 2006)**

AGRICULTURAL WASTE and BIOWASTE AS ADSORBENTS

Agricultural waste materials are viable option for waste water treatment due to eco- friendly and economic nature, unique chemical composition, availability in abundance and renewable in nature

The adsorption of Alizarin Red-S dye on coconut shell activated carbon (CSAC) was investigated using batch adsorption technique. The adsorbent was also characterised by FTIR, SEM, EDAX studies. The studies shows that a CSAC can be an alternative to other expensive adsorbent used for the removal of dyes from aqueous solution. **(Wagah *et al*., 2014)**

Activated carbon was prepared from date palm seeds and it was used for the removal of Alizarin Red dye. The evaluation of the thermodynamic parameters showed that the adsorption process was spontaneous and endothermic. The uptake increased with increasing agitation time, concentration of dye solution and temperature. The kinetic data obtained from this study showed good correlation coefficient for the pseudo-first order kinetic model. **(Nasiru Abdus-Salam *et al*.,2016)**

Phenolic resin and waste cotton fiber was evaluated as an adsorbent for Alizarin Red S dye removal in batch mode adsorption. The increase of pH and temperature reduces the adsorption of ARS but with the increases in initial concentration of ARS its adsorption increases. The best isotherm equilibrium has been achieved with a Freundlich model.
(Bechir Wanassi *et al*., 2017)

The activated carbon derived from Achyranthes aspera plant (ACAA) was used for the removal of Alizarin Red-S dye by adopting batch modes using simulated water. The adsorption process is analysed using Langmuir and Freundlich isotherms and found that Langmuir model better describes the adsorption process. The FTIR data also confirms the adsorption of dye on to the surface of the adsorbent. **(Sujitha *et al*.,2016)**

Cynodon dactylon was used as an adsorbent for Alizarin Red-S dye removal from aqueous media. The optimum conditions for the removal of Alizarin Red with Cynodon dactylon are: 0.6 g of adsorbent dose, dye concentration 25 ppm, pH=1 at 30°C. **(Samusolomon *et al*.,2011)**

Studies on Alizarin Red-S dye removal were carried out in batch culture under both shaking and static conditions using Bulkholderia.sp. The maximum decolourization (89%) was observed at pH=5 at inoculum concentration of 20%. **(Richa Sharma *et al*.,2015)**

An activated carbon prepared from mango seeds (MGA) was used as an adsorbent for Alizarin Red-S dye removal. The adsorption data for Alizarin Red-S on MGA confirmed well to the Langmuir isotherm with a high correlation coefficient close to unity. The evaluated thermodynamic

quantities supported physical, spontaneous and endothermic adsorption process. **(Nasiru Abdus- Salam *et al*., 2014)**

Citrullus lanatus peels was used for the removal of Alizarin Red-S dye. The adsorption process was found to be physio- sorption, dominating over chemi-sorption mode of removal of dye, followed pseudo-second order model. Thermodynamic and kinetic investigations revealed that this process was favourable and endothermic in nature**. (Rabia Rehman *et al*., 2013)**

Abelmoschus esculentus stem powder was used for adsorptive removal of Alizarin Red S. Langmuir isothermal modelling of adsorption data showed that monolayer chemisorption of Alizarin Red S dyes occurred well on homogenously distributed binding sites of adsorbent Maximum adsorption capacity of Abelmoschus esculentus stem powder was 75.06mg.g-1**. (Rabia Rehman *et al*., 2013)**

Snail shell used as an adsorbent for the removal of Alizarin red S. The adsorption isotherms could be well- defined with the Temkin isotherm model instead of the Freundlich isotherm model. The optimum removal of Alizarin Red S obtained at pH 2 **.(Muneer A Al-Da'amy *et al*., 2018)**

Parimal Chandra Bhomick *et al*.,(2018) describes the synthesis of activated biocarbon from Pinus kesiya $ZnCl_2$ activation and it's efficiency in the removal of Alizarin Red S. The adsorption isotherm was well defined by Langmuir model. Kinetic studies established the overall rate to be controlled by chemisorption.

Noureddine Barka *et al*., (2013) investigated dried prickly pear cactus cladodes as eco- friendly low cost adsorbent for the removal of Alizarin Red S. The experimental isotherm data were analyzed using Langmuir, Freundlich, Redlich- Peterson, Temkin and Toth isotherm equations. The best fit was obtained by the Redlich- Peterson model and the Langmuir model.

Ravindra k. Gautam *et al*., (2014) studied the adsorption of Alizarin Red S onto biosorbent of Lantana camara on aqueous solution. The adsorption was also found to be highly dependent on pH with higher

removals observed at pH range 2- 3. The adsorption process followed the pseudo- second –order rate kinetics. Freundlich isotherm model fitted well very well with the equilibrium adsorption data.

El- Said. A.G *et al.*, (2012) was used orange peel as a low cost natural waste adsorbent for the removal of Alizarin Red S from textile effluents. The pH value had a great influence on the adsorption efficiency, at pH 3, the adsorption efficiency was found to be 75%. The adsorption models followed Langmuir and Freundlich adsorption isotherm models and pseudo second order rate equation.

Activated carbon prepared from Allium cepa by heating in an oven was used an adsorbent for removal of Alizarin Red S. Optimum conditions for the removal of Alizarin Red-S dye with Tunic of Allium cepa are:
pH= 3.5, adsorbent dosage= 1.5 g, contact time = 120 mins and temperatue = 30°C.The adsorption efficiency was found to be 40%.
(Sumalatha Mallipudi *et al.*, 2013)

Mohammadine El Haddad *et al.*, (2014) considered calcined mussel shells (CMS) as a low cost and eco- friendly biosorbent for the removal of Alizarin Red S. The kinetic study of dye into CMS followed the pseudo second order model. The biosorption pattern of dye was well described by Langmuir isotherm model.

Pavan Kumar Gautam *et al.*, (2017) investigated the efficiency of biosorbent prepared from Mikania micrantha in the removal of Alizarin Red S from aqueous solution. Morphological and constitutional characteristics of the biosorbent were studied by performing Scanning Electron Microscopy and Fourier Transform InfraRed spectra. The negative values of ΔG^{o} and positive value of ΔH^{o} demonstrated that the adsorption of Alizarin Red S onto the Mikania micrantha were spontaneous and endothermic in nature.

Rais Ahmad *et al.*, (2008) investigated the adsorption of Alizarin Red S from aqueous solution onto the agricultural mentha waste by varying parameters such as pH, dye concentration, adsorbent dosage and temperature.

The adsorption followed Langmuir and Freundlich adsorption isotherm models. The adsorption efficiency was found to be 8mg/g at 50°C.

Ahmad B. Albadarin *et al.*, (2015) investigated the adsorption of Alizarin Red S using olive stove biomass. The biosorption experimental data for Alizarin Red S was well suited to the Redlich-Peterson isotherm. The kinetic data of the dye was better described by the pseudo-second –order model . From the diffusion models, it was concluded that film-diffusion or chemical reaction controls the rate of biosorption.

Mustard husk was used as a biosorbent for Alizarin Red S from aqueous solution. The thermodynamic studies showed that the Alizarin Red S biosorbent system was spontaneous, exothermic and favourable in nature and the adsorption was also found to be highly dependent on pH, with higher removal observed at pH range 2-3. **(Ravindra K.Gautam *et al.*,2014)**

Activated Clay modified by Iron oxide was used as an adsorbent for the removal of Alizarin Red S dye. The pH had a great influence on the adsorption efficiency. The adsorption efficiency was found to be 98% at pH= 4.15 within 60 minutes of contact time. The adsorption followed Langmuir adsorption isotherm model and pseudo- second order equation. **(Feng Fu *et al.*, 2011)**

Activated carbon prepared from activated cotton stalks by heating at 120°C was used as an adsorbent for the removal of Alizarin Red S dye. The pH had a great influence on the adsorption efficiency, At pH=5 the adsorption efficiency was found to be 196.08 mg/g. The adsorption followed Freundlich adsorption isotherm model.**(Mustafa ozdemir *et al.*, 2015)**

Sn_2O nanoparticles loaded on Activated carbon obtained from Phaseolus lunatus L.leaves was used as an adsorbent for the removal of Alizarin Red S dye. The characteristic studies were performed by X-Ray Diffraction, Fourier Transform Infrared Spectroscopy and Scanning Electron Microscopy. The adsorption efficiency was found to be 99% at pH=5 within 45 minutes of contact time. **(Shamima Begum *et al.*, 2018)**

Activated carbon/ γ- Fe_2O_3 used as an adsorbent for the removal of Alizarin Red S dye from aqueous solution by varying parameters such as pH, concentration of the dye, amount of adsorbents and contact time. The adsorption followed Langmuir adsorption isotherm model and pseudo second order rate equation. **(Maryam Fayazi *et al.*, 2015)**

Carbonaceous adsorbents derived from textile cotton waste was used as an adsorbent for the removal of Alizarin Red S dye. The pH value and temperature had a great influence on the adsorption efficiency. The adsorption efficiency was 75% at pH= 3 and temperature at 25°C. The adsorption followed Langmuir Adsorption isotherm model, Freundlich adsorption isotherm model and Sips adsorption isotherm model. **(Bechir Wanassi *et al.*, 2017)**

Activated carbon prepared from Rice Husk by heating in an oven was used as an adsorbent for the removal of Alizarin Red S dye. The adsorbent dosage value had a great influence on the adsorption efficiency. The increase in adsorbent dosage increases the adsorption efficiency. The adsorption efficiency was found to be 98% at 10gram of adsorbent dosage. **(Khonde. R.D., *et al* 2012)**

INDUSTRIAL WASTE AS ADSORBENT

Industrial activities generate huge amount of solid waste materials as by-products. The industrial waste material is available almost free of cost and causes disposal problem. If the solid wastes could be used as adsorbents, the volume of waste materials can be partly reduced as well as the pollution of wastewater can be reduced at reasonable cost. Thus, a number of industrial wastes with or without treatment have been investigated as adsorbents for the removal of pollutants from wastewater.

Borassus powder used as a new adsorbent for the removal of Alizarin Red S. The characterisation of the biosorbent was performed by using Fourier Transform InfraRed spectra and X-Ray Diffraction techniques. The kinetic studies shows that the biosorption of Alizarin Red S is described both pseudo first order and pseudo second order kinetics. **(Raju *et al.*, 2018)**

Bacterial strains isolated from industrial effluents used as an adsorbent for removal of Alizarin dye. The optimal conditions for decolourisation of Alizarin Red for both Pseudomonas sp. and Escherichia coli was to be 1% glucose, 1% peptone, pH= 7.0 and 500mg/L dye concentration. Decolourisation of Alizarin Red was confirmed by UV/VIS spectrophotometry. **(Illakkaiam *et al*.,2016)**

Beigang Li *et al*., (2012) used Ultra-fine Fly Ash, a low cost industrial solid waste removed Alizarin Red-S from aqueous solution. The Alizarin Red-S uptake process followed the pseudo-second-order rate equation well but the pseudo –first-order equation and intra particle diffusion equation could be applied to describe the initial stages of adsorption. Langmuir isotherm equation could better describe the adsorption equilibrium at different temperature, compared with Freunlich model.

NANO PARTCLES AS ADSORBENT

Cobalt hydroxide nanoparticles used as an adsorbent for the removal of Alizarin Red S from the aqueous solution. The positive value of ΔH^{o} (enthalpy) suggests the endothermic nature of adsorption. The positive value of ΔS^{0} (entropy) confirms the increased randomness at solid- solution interface during adsorption. **(Javad Zolgharnein *et al*., 2016)**

Deliang Li *et al*., (2011) investigated the adsorption of Alizarin Red S onto Nano-sized Silica modified with γ-Aminopropyltriethoxysilane (AMNS). The experimental isotherm data were analysed using Langmuir and Freundlich equation. The adsorption of ARS onto AMNS followed the Langmuir model, the maximum adsorption capacity being estimated as 200mg/g.

The nanostructure of γ- alumina was used as an adsorbent for removing mixture of Alizarin Red and Alizarin Yellow dyes. Optimum conditions for the removal of Alizarin Red-s with γ- Alumina nanoparticles are: pH= 5, temperature= 25°C, contact time= 20mins and adsorbent dosage= 8g/L. The adsorption followed Langmuir adsorption isotherm model and pseudo-second order rate equation. **(Javad Zolgharnein *et al*., 2014)**

Catalpa Bignonioides leaves and Zinc nanoparticle was used for the removal of Alizarin Red dye. The characterization techniques involved comprises of X-Ray Diffraction and Fourier Transform InfraRed spectra. The maximum dye decolourization of ARS on to Catalpa Bignonioides leaves with zinc oxide nano solution observed when the processing parameters are t=30 hours, pH=5, w=10 ml and T=303 K is 83%. **(Raju *et al*., 2017)**

Fe_3O_4 nanoparticles used for removal of Alizarin Red S from Aqueous solution. The kinetic results revealed that the pseudo-second-order equation is the best model to analyse the adsorption mechanism. The isotherm modelling revealed that the Langmuir equation could better describe the adsorption of Alizarin dye on to the Fe_3O_4 nanoparticle as compared to Freundlich model. **(Ghodratollah Avsalan *et al*., 2017)**

Polypyrrole- coated Fe_3O_4 nanoparticle was used for the removal of Alizarin Red S from aqueous solution. The adsorption process followed pseudo- second order kinetic model and the equilibrium data fitted well in the Langmuir isotherm model good.
(Mohammad Bagher Gholivand *et al*., 2015)

Poly- 2- hydroxyethyl methacrylate (PHEMA) was used as an adsorbent for the removal of Alizarin Red S. Thermodynamic studies revealed the feasibility and endothermic nature of the system. The obtained experimental kinetic data was well fitted with pseudo- second order model**.**
(Hamidreza Sadegh *et al*., 2015)

Sui Wang *et al*., (2013) investigated magnetic sulphonic Graphene Nanocomposite used as a adsorbent for the removal of Alizarin Red S. Adsorption kinetic followed the pseudo-second-order kinetic model well. The adsorption isotherm coincided with Langmuir and Freundlich adsorption models.

Abideen Idowu Adeogun *et al*., (2015) studied the removal of Alizarin Red -S using Calcuim phosphate hydroxyapatite (Ca-Hap) from its aqueous solution. The pH and contact time had a great influence on the adsorption efficiency. The adsorption efficiency was found to be 90% at pH

7 in 30 minutes of contact time. The adsorption followed Langmuir adsorption isotherm model and pseudo- second order equation.

Electrocoagulation (EC) was used for the removal of Alizarin Red-S dye from aqueous solution. The adsorption depended on the temperature, pH and initial dye concentration. The adsorption followed Dubinin-Radushkevich isotherm and Sips isotherm model**.** **(Abideen Idwu Adeogun *et al*., 2016)**

Alizarin Red-S in aqueous solution was studied using Fenton like reaction in dark environment. Increasing temperature in the range of 298-313 K increases the rate of degradation and no optimal value detected. The rate of decolourization is decreased by increasing the concentration of dye and addition of carbonate. **(Abou Gamra., 2014)**

The crystalline mixed oxide $Cu_{0.5}$ $Zn_{0.5}Ce_3O_5$ was used as an adsorbent for Alizarin Red S. The characteristic studies were performed by X-Ray Diffraction, Scanning Electron Microscopy and Transmission Electron Microscopy. The adsorption followed both Langmuir and Freundlich isotherms but better results obtained with Freundlich model. The removal of Alizarin from aqueous solution depended on the adsorbate concentration and temperature but less depend on the pH of solution**.**
(Jadhav. H.V *et al*.,2011)

α- Fe_2O_3/ NiS has been used for the removal of Alizarin Red S from aqueous media. Optimum conditions for the removal of Alizarin red S with α-Fe_2O_3/ NiS are:1g of adsorbent, dye concentration 50ppm, at 25°C and at pH of 5.0. **(Hadi Roopaei *et al*., 2014)**

Mamat. M *et al*., (2018) studied nickel/aluminium layered double hydroxide as a potential adsorbent for Alizarin Red- S dye removal from aqueous solution. Optimum conditions for the removal of Alizarin red-S with Nickel Aluminium layered double hydroxide was found to be 0.25g of adsorbent dosage, dye concentration = 40 ppm and contact time = 60 minutes. The adsorption followed Langmuir adsorption isotherm model.

Nanospheres of Mn_3O_4 used as an adsorbent for the removal of Alizarin red S dye. The characteristics of the adsorbent were studied by X-Ray powder Diffraction and Transmission Electron Microscopy. The adsorption followed Langmuir adsorption isotherm model. The adsorption efficiency was found to be 28.72 mg/g. **(Ming yang *et al.*, 2010)**

$CuCl_2$ doped polyaniline composite used as an adsorbent for the removal of Alizarin Red S dye. The temperature had a great influence on the adsorption efficiency, At 30°C the adsorption was found to be 98%. The adsorption followed Langmuir adsorption isotherm model and pseudo second order equation**. (Anusha.D *et al* ., 2018)**

Ionic liquid- Modified Fe_2O_4 nanoparticle was used as an adsorbent for the removal of Alizarin Red S dye. Optimum conditions for the removal of Alizarin Red S dye with Ionic liquid- Modified Fe_2O_4 nanoparticle are pH= 3.0, Adsorbent dosage = 5.0 mg, Contact time = 20 minutes and dye concentration= 20 ppm. The adsorption efficiency was found to be 98%.
(Sedigheh Kamran *et al*., 2018)

$CoFeO_4$ nanoparticle was used as an adsorbent for the removal of Alizarin Red S dye. The contact time had a great influence on the adsorption efficiency. The adsorption capacity was found to be 98% within 20 minutes, the adsorption followed Langmuir adsorption isotherm model and pseudo-second order rate equation. **(Sedigheh Kamran *et al*., 2018)**

Fe_3O_4 magnetic nanoparticles was used as an adsorbent for the removal of Alizarin Red S dye.Optimum conditions for the removal of Alizarin Red S dye with Fe_3O_4 magnetic nanoparticles are: Adsorbent dosage= 20 mg, Dye concentration= 20 ppm, Contact time= 5 minutes and Temperature= 34°C. The adsorption followed Langmuir adsorption isotherm model**. (Ghodratollah Absalan *et al*., 2017)**

Catechol- Amine resin composite was used as an adsorbent for the removal of Alizarin Red S dye. The characteristic studies were performed by Scanning Electron Microscopy, Fourier Transform Infrared Spectroscopy, X-

Ray Photoelectron Spectroscopy. The adsorption of Alizarin Red S onto the Catechol- Amine resin composite by varying parameters such as adsorbent dosage, contact time, initial dye concentration and temperature. The adsorption followed Langmuir adsorption isotherm model and pseudo-second order equation. **(Quiang Liu *et al.*, 2016)**

Cetyltrimethylammonium bromide (CTAB) - modified TiO_2 nanoparticles was used as an adsorbent for the removal of Alizarin Red S dye. Optimum conditions for the removal of Alizarin red S dye with Cetyltrimethylammonium bromide (CTAB) - modified TiO_2 nanoparticles are: pH= 2, Temperature = 30°C, Adsorbent dosage = 0.05g and Dye concentration= 232ppm. The adsorption efficiency was found to be 92%. **(Javad Zolgharnein *et al*., 2014)**

Carbon nanotubes was used as an adsorbent for the removal of Alizarin Red S dye. The negative value of ΔH°(enthalpy) signify that the interaction of carbon nanotube with Alizarin Red S dye is exothermic. The negative value of ΔG° (Gibbs free energy) shows that adsorption of Alizarin Red S dye onto the carbon nanotube was spontaneous.
(Fernado M. Machado., 2016)

Polyvinyl chloride / Carbon nanotube nanocomposite fibers was used as an adsorbent for the removal of Alizarin Red S dye. The characteristic studies were performed by Raman spectroscopy, X- Ray Photoelectron Spectroscopy, Scanning Electron Microscopy and X- Ray Diffraction. The thermodynamic study revealed that adsorption of Alizarin red S dye was endothermic. **(Mudassir Hasan *et al*., 2012)**

As- Synthetic Graphene oxide was used as an adsorbent for the removal of Alizarin Red S dye. Optimum conditions for the removal of Alizarin red S dye with Graphene oxide are: Dye concentration= 350 mg, Adsorbent dosage = 0.02 mg, pH= 2.0 and contact time = 30 minutes. The adsorption efficiency was found to be 88.05mg/g. **(Prawit Nuengmatcha *et al* ., 2016)**

Nano- Fe_3O_4 and corn cover composite was used as an adsorbent for the removal of Alizarin Red S dye from aqueous solution by varying parameters such as pH, temperature, adsorbent dosage and initial dye concentration. The adsorption followed Langmuir adsorption isotherm model, Freundlich adsorption isotherm model and Dubinin Radushkevich adsorption isotherm model. **(Zolgharnein. J *et al*., 2016)**

DISCUSSION

DISCUSSION

In the present study analysis of nearly hundred Eco- friendly, low cost adsorbents used for the removal of Alizarin red S dye from aqueous solution is discussed. The experimental conditions at which maximum removal of Alizarin red S dye obtained using these low- cost adsorbents is listed in the following data

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Lantana camara	Alizarin Red	500 mg	25 ppm	90 min	29°C	2	99.2%
Pine cone biomass	Alizarin Red	30 mg	100 ppm	80 mins	29°C	2	99%
Activated Carbon/ γ- Fe_2O_3 Nano composite	Alizarin Red	10 mg	70 ppm	60 mins	25°C	2	99%
SnO_2 Nanoparticles loaded on Activated Carbon	Alizarin Red	15 mg	3.55 ppm	45 mins	28°C	5	99 %
Nano γ- Alumina	Alizarin Red	8000 mg	0.06mmol/L	20 mins	25°C	5	99%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Zn/ Al – CO_3	Alizarin Red	80 mg	20 ppm	180 mins	40°C	12	99 %
Fe_3O_4 Magnetic nano particle	Alizarin Red	20 mg	20ppm	5min	34^0C	5	99%
$CoFe_2O_4$	Alizarin Red	5mg	20ppm	20min	15^0C	9	98%
Fe_3O_4 Nanoparticles	Alizarin Red	5mg	20ppm	20min	114^0C	9	98%
CTAB modified PVA-Alginate bound nano magnetite microsphere	Alizarin Red	250 mg	25 ppm	150 mins	25°C	8	98%
Ionic liquid Modified-Fe_3O_4 nanoparticles	Alizarin Red	5.0 mg	20 ppm	20 mins	114.8°C	3	98%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Activated clay modified by Iron oxide	Alizarin Red	4000 mg	400 ppm	60 mins	25°C	4	98%
Rice Husk carbon	Alizarin Red	10000 mg	100 ppm	60 mins	25°C	2	98%
$CuCl_2$ doped polyaniline	Alizarin Red	300 mg	20 ppm	5 mins	45°C	4.73	97%
Nano- sized silica modified with γ-aminopropyltriethoxy silane	Alizarin Red	150 mg	500 ppm	5 mins	20°C	2.2	97%
Polymer coated Iron oxide magnetic nanoparticle	Alizarin Red	20 mg	100 ppm	48 hours	27°C	7	96%
Zero valent metallic Iron with Ammonium persulphate	Alizarin Red	50 mg	200 ppm	10 mins	27°C	3	96%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Zero valent metallic Iron with Hydrogen peroxide	Alizarin Red	50 mg	100 ppm	10 mins	27°C	3	96%
Fe(III) treated hydroxyapatites- 400 in Phosphate Buffer Solution	Alizarin Red	10 mg	0.1 mM	30 hours	25°C	6.8	95%
N-methyl imidazolium anion exchange resin	Alizarin Red	10 mg	150 ppm	10 hours	24.8°C	5.7	95%
Calcuim Phosphate Hydroxyapatite	Alizarin Red	100mg	50ppm	30min	30^0C	7	95%
Magnetite with H_2O_2	Alizarin Red	2000 mg	100 ppm	120 mins	25°C	7	93.5%
Magnetite with soluble hematin	Alizarin Red	25 mg	100 ppm	120 mins	25°C	7	93%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Phenyl / Amine end-capped tetra aniline	Alizarin Red	2000 mg	300 ppm	10 mins	24.8°C	5	93%
Ni Fe_2O_4/ Polyaniline	Alizarin Red	30 mg	30 ppm	20 mins	29.8°C	8	93%
Cetyltrimethyl ammonium bromide-modified TiO_2 nanoparticles	Alizarin Red	50mg	232ppm	90 min	30^0C	2	92%
Activated carbon engrafted with Ag nanoparticle	Alizarin Red	10 mg	15 ppm	140 seconds	27^0C	6	91.5%
Mango seed activated carbon	Alizarin Red	250mg	30 ppm	90 min	35^0C	4	90.4%
Iron(III) ions and hydrogen peroxide	Alizarin Red	8 ×10-3 Mol dm-3	2 × 10-4 Mol dm-3	15 min	30^0C	2	90%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Activated charcoal	Alizarin Red	200mg	20ppm	1 hour	25^0C	2	90%
Ultra Fine Ash	Alizarin Red	10000 mg	700ppm	60 mins	25°C	5	90%
Calcuim-Phosphate based material	Alizarin Red	100 mg	50 ppm	30 mins	30°C	7	90%
Calcium hydroxide	Alizarin Red	800mg	600ppm	180 min	24^0C	12	90%
Citrullus lanatus	Alizarin Red	300mg	20 ppm	40 min	20^0C	1	89.4%
Activated carbon from achyranthes aspera plant	Alizarin Red	5000mg	100ppm	15 min	30^0C	2	89%
Burkholderia Sp	Alizarin Red	50 mg	100 ppm	2 min	30^0C	5	89%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Cynodan dactylen	Alizarin Red	600mg	25ppm	60 min	30^0C	1	88.7%
Snail Shell	Alizarin Red	100 mg	30 ppm	10 mins	25°C	2	88.4%
α-Fe_2O_3/NiS	Alizarin Red	1000 mg	50 ppm	10 min	25^0C	5	88%
Coconut shell activated carbon	Alizarin Red	4000mg	60ppm	120 min	25^0C	8	86%
TiO_2 and ZnO	Alizarin Red	200mg	20 ppm	120 min	12^0C	8	84.4%
Zinc nano Particle from Catalpa Bignonioides	Alizarin Red	10000mg	20 ppm	30 hrs	30^0C	5	83%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Nano crystalline $Cu_{0.5}$,$Zn_{0.5}$, Ce_3o_5	Alizarin Red	50 mg	10 ppm	5 min	25^0C	3	83%
Chitosan ZnO	Alizarin Red	100 mg	20 ppm	48 hrs	25^0C	2	82%
UiO-66	Alizarin Red	24.8 mg	11.82 ppm	36 mins	24°C	2	81%
Mustard Husk	Alizarin Red	500 mg	25 ppm	90 mins	30°C	2	80.2%
Fe_3O_4 @ NH_2 @PEI	Alizarin Red	1000 mg	100 ppm	20 mins	25°C	3	80%
Nano Fe_3O_4/ Corn composite	Alizarin Red	200 mg	10 ppm	70 mins	24.8°C	2	80%
Calcined mussel shells	Alizarin Red	200 mg	75 ppm	90 mins	35°C	2	79%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
NaCl electrolyte with Aluminium electrode	Alizarin Red	2000mg	25ppm	10 min	30^0C	7	78.5%
Mg Al- CO_3	Alizarin Red	80 mg	20 ppm	180 mins	40°C	12	78%
Polypyrrole coated magnetic nanoparticle	Alizarin Red	100 mg	20 ppm	35 mins	23°C	4	78%
Orange Peel	Alizarin red	40 mg	20 ppm	60 mins	25°C	3	75%
Carbonaceous adsorbents dervived from textile cotton waste	Alizarin Red	200 mg	100 ppm	1440 hours	25°C	3	75%
Nickel/ Aluminium Double layered hydroxides	Alizarin Red	250 mg	40 ppm	60 mins	27°C	6	73%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Pseudomonas sp	Alizarin Red	1000mg	500ppm	12 hrs	37^0C	7	72%
Alumina	Alizarin Red	25mg	25ppm	15 min	30^0C	1	71%
Chitosan Lignin Composites	Alizarin Red	47 mg	50 ppm	3 hours	27°C	2	71%
Poly-2 – hydroxy ethyl methacrylate	Alizarin Red	500 mg	20 ppm	50 mins	24°C	8	70%
Borassus powder	Alizarin Red	10000mg	20 ppm	40 mins	34°C	6	70%
Echerichia coli	Alizarin Red	1000mg	500 ppm	12 hrs	37^0C	7	68%
Nano Fe_3O_4	Alizarin Red	100 mg	50 ppm	70 mins	24.8°C	2	65.5%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
MgZn/Al- CO_3	Alizarin Red	80 mg	20 ppm	180 mins	40°C	12	65 %
Palm seeds activated charcoal	Alizarin Red	30 mg	500ppm	90 min	35^0C	9	61%
Fe(III) treated hydroxyapatites- 400 in H_2O	Alizarin Red	10 mg	0.1 mM	30 hours	25°C	7	55%
Alumina carbon composite	Alizarin Red	40mg	102ppm	20 min	30^0C	5	52%
Single walled carbon nanotubes	Alizarin Red	30 mg	800 ppm	65 mins	24°C	2	50%
Hydroxyapatites-400 in H_2O	Alizarin Red	10 mg	0.1 mM	30 hours	25°C	7	50%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Multi walled carbon nanotubes	Alizarin Red	30 mg	800 ppm	100 mins	24°C	2	48%
Mikania micrantha	Alizarin Red	100 mg	25 ppm	60 mins	50°C	2	46.5%
Pb(III) treated hydroxyapatites- 400 in H_2O	Alizarin Red	10 mg	0.1 mM	30 hours	25°C	7	45%
Pyridine functionalized silane	Alizarin Red	100mg	10000ppm	2hrs	25^0C	3.5	40%
Tunic of Allium cepa	Alizarin Red	1000 mg	10000 ppm	120 mins	30°C	3.5	40%
Magnetic- Sulphonic Graphene nanocomposite	Alizarin Red	1000 mg	100 ppm	10 mins	23°C	6	40 %
Magnetic chitosan	Alizarin Red	100 mg	100 ppm	50 mins	30^0C	3	40%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Activated carbon	Alizarin Red	50mg	75ppm	7 min	25^0C	2	38.5%
Olive stone	Alizarin Red	5000 mg	110 ppm	72 hours	20°C	3.2	34.2%
Catechol- amine Resin composite	Alizarin Red	50 mg	150 ppm	6 hours	30^0C	7	28.4%
Magnetite	Alizarin Red	100 mg	75 ppm	2 hrs	30^0C	3	26 %
Oxygen- rich pentaerythritol modified multi-walled carbon nanotube	Alizarin Red	5.0 mg	150 ppm	120 mins	44.8°C	8	25.37%
Hydroxyapatites-400 in Phosphate Buffer Solution	Alizarin Red	10 mg	0.1 mM	30 hours	25°C	6.8	25%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Geothite	Alizarin Red	50 mg	75 ppm	2 hrs	30^0C	3	23%
Pb(III) treated hydroxyapatites in Phosphate Buffer Solution	Alizarin Red	10 mg	0.1 mM	30 hours	25°C	6.8	20%
Activated Cotton stalks	Alizarin Red	50 mg	100 ppm	180 mins	30°C	5	19.8%
Fe(III) treated Hydroxyapitates-300 in Phosphate Buffer solution	Alizarin Red	10 mg	0.1mM	30 hours	25°C	6.8	16%
Polyvinyl Chloride/ Carbon nanotube	Alizarin Red	200 mg	20 ppm	100 mins	25°C	2	15%
Cobalt hydroxide nanoparticles	Alizarin Red	351 mg	43 ppm	40 mins	27°C	5.5	13.2%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Gold Nanoparticles loaded on activated carbon	Alizarin Red	15 mg	35 ppm	5 mins	24.8°C	4.2	12.3%
Dried prickly pear cactus	Alizarin red	500 mg	100 ppm	90 mins	25°C	5.2	11.8%
Pb (III) trated hydroxyapitates-300 in H_2O	Alizarin Red	10 mg	0.1mM	30 hours	25°C	7	11%
Phenolic resin and waste carbon fiber	Alizarin Red	1000mg	5 ppm	24 hour	25^0C	3	10.4%
Hydroxyapitates-300 in H_2O	Alizarin Red	10 mg	0.1mM	30 hours	25°C	7	10%
Fe (III) trated hydroxyapitates- 300 in H_2O	Alizarin Red	10 mg	0.1mM	30 hours	25°C	7	9%
As- synthetic Graphene oxide	Alizarin Red	0.02 mg	350 ppm	180 mins	29.8°C	2	8.85%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Abelmoschus esculentus stem powder	Alizarin Red	3000mg	100 microns	50 mins	30°C	3	7.5%
Polyvinyl chloride	Alizarin Red	200mg	20 ppm	100 mins	25°C	2	7%
Porous Xerogels	Alizarin Red	500 mg	100 ppm	5 days	25°C	2	7%
Mentha waste	Alizarin Red	500 mg	50 ppm	120 mins	30°C	2	7%
Pyridine Functionlised mesoporous silica	Alizarin Red	100 mg	1mM	10 mins	25°C	3.5	5.1%
Chitosan	Alizarin Red	100 mg	50 ppm	2 hrs	30^0C	5	4%

Adsorbent	Dye Removed	Adsorbent dose	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed
Pb (III) trated hydroxyapitates- 300 in phosphate buffer solution	Alizarin Red	10 mg	0.1mM	30 hours	25°C	6.8	3.8%
Bare Graphite	Alizarin Red	0.02 mg	350 ppm	180 mins	29.8°C	2	3.42%
Corn composite	Alizarin Red	100 mg	50 ppm	70 mins	24.8°C	2	2.8%
Mn_3O_4 Nanoparticles	Alizarin Red	200 mg	40ppm	5 mins	30° C	6	2.8%

CONCLUSION

CONCLUSION

The research paper collected revealed about various low- cost adsorbents obtained from agricultural, industrial and other waste materials used for the removal of Alizarin Red-S dye from aqueous solution by adsorption.

The following conclusions are dervived after thoroughly going through the research articles collected

a) Percentage removal of Alizarin Red S dye increased with decrease in concentration of dye solution due to the availability of more number of active sites on the surface of the adsorbent for adsorbent for less number of dye species due to low concentration of the dye solution.
b) As the dosage of the adsorbents increases the percentage removal of the dye also increases due to the greater surface area available for the adsorption of more number of dye species.
c) Smaller the particle size, greater is the surface area available for adsorption therefore percentage removal of Alizarin Red S dye increases with decrease in the particle size of the adsorbent.

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