

Umbrella Memorandum of Understanding

Memorandum of Understanding

Between

Government College of Arts & Science, Aurangabad

And

Government Institute of Science, Aurangabad

Both the above mentioned parties wishing to develop friendly and cooperative relations in the fields of education and research have agreed to establish the present Memorandum of Understanding (MOU).

I Subject of the Agreement

Both parties agree to explore the following general forms of cooperation:

1. Joint educational, training and/or research activities.
2. Exchange of invitations to scholars (Faculty, research personal and graduate students) for lectures, visits and sharing of experiences.
3. Exchange of invitations to scholars for participation in conferences, symposia and seminars.
4. Exchange of information in fields of interest to both parties.
5. Exchange of faculty, research personnel graduates and under graduate students for study and research.
6. Practical training in pre-identified or otherwise selected field sites.

Before proceeding with any such activities, the parties shall discuss whether it is advisable to enter into a specific agreement that includes additional terms and conditions regarding costs, intellectual property, liability, and other matters as the circumstances may require.

II. Obligation of the Parties

To implement the MOU the parties commit themselves to provide necessary conditions:

- 2.1. Both sides will maintain on going communications and circulate essential information in a timely manner.
- 2.2. Both parties agree that all financial agreements necessary to implement this MOU must be negotiated and will depend upon the availability of funds. Neither institution shall have any financial obligation to the other institution based this agreement.
- 2.3. Realization of separate concrete research projects within the frames of the MOU will be stipulated in separate, specific agreements.

III. Term and order and action.

3.1. This MOU will become effective upon the date of signature by the representatives of the institutions and, if applicable, approval by appropriate authorities.

3.2. Either party wishing to make changes or terminate the MOU shall notify the other partner in writing of such intentions no later than three months before the suggested changes should go into effect.

3.3. Each party reserves the right to unilaterally terminate the MOU should the other partner fail to fulfil its responsibilities as stated here in.

IV. Responsibilities of the parties

4.1. Each party acts on its own behalf in all relations with a third party. Neither party will be responsible for any outside commitments of the other party.

4.2. The parties shall remain independent of one another and nothing here in shall be construed or interpreted, by implication or otherwise to form a partnership, agency, joint venture or other formal business association.

4.3. Both institutions subscribe to the policy of equal opportunity and do not discriminate on any basis, including but not limited to race, caste, sex, age, ethnicity, religion or national origin.

V. Signatures

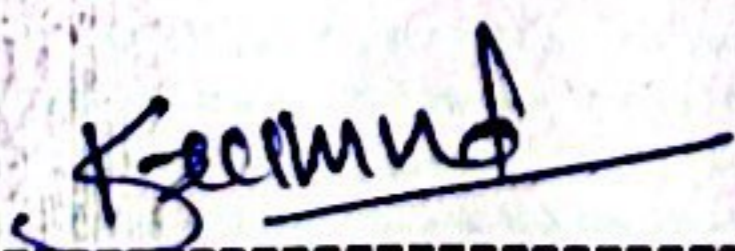
The MOU is written signed in four copies having equal force, each party receiving two copies for the record.

VI. Legal addresses of the parties

Party 1 st	Party 2 nd
GOVERNMENT COLLEGE OF ARTS AND SCIENCE, AURANGABAD.	GOVERNMENT INSTITUTE OF SCIENCE AURANGABAD. 413002, (M.S.), INDIA

SIGNATURES OF THE PARTIES WITH DATE:

PARTY 1st



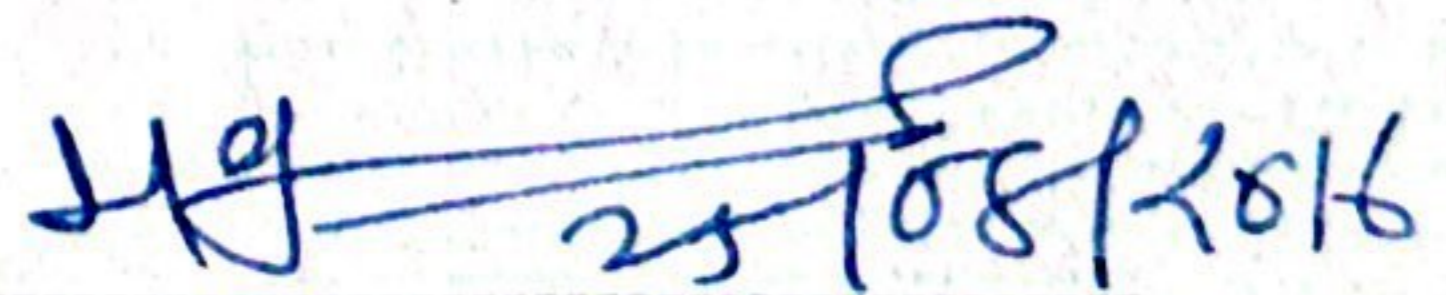
Principal

Authority Name: Dr. Kumudkherdekar (Gore)
Aurangabad.



Seal of the Institute:

PARTY 2nd



Director

Authority Name: Dr. Hemlata Wankhede
Aurangabad.



Seal of the Institute:



**GOVERNMENT OF MAHARASHTRA
GOVERNMENT COLLEGE OF ARTS & SCIENCE,
AURANGABAD**

Phone No. 0240- 2331476

gasca1923@gmail.com

Fax No. - 0240- 2331476

GASCA/2022-23/1779

Date: 28/09/2022

To,

**Dr. Suchita Bharambe
Assistant Professor,
Department of Microbiology
Government Institute of Science,
Aurangabad**

Subject: Invitation as Resource person under MoU for Remedial Support

Dear Madam,

It's our pleasure to invite you as a Resource person in Department of Microbiology, Government College of Arts And Science, Aurangabad to guide our students on "Hands on Training on Laboratory Techniques" under MoU for Remedial Support.

I am requesting you to accept our invitation and enlighten our students by sharing your deep knowledge.

Awaiting for your positive response
Thanking you

Date: 03rd October 2022 (Monday)

Time: 02:00 pm

Venue: Department of Microbiology



Yours Sincerely

[Signature]
28.9.22

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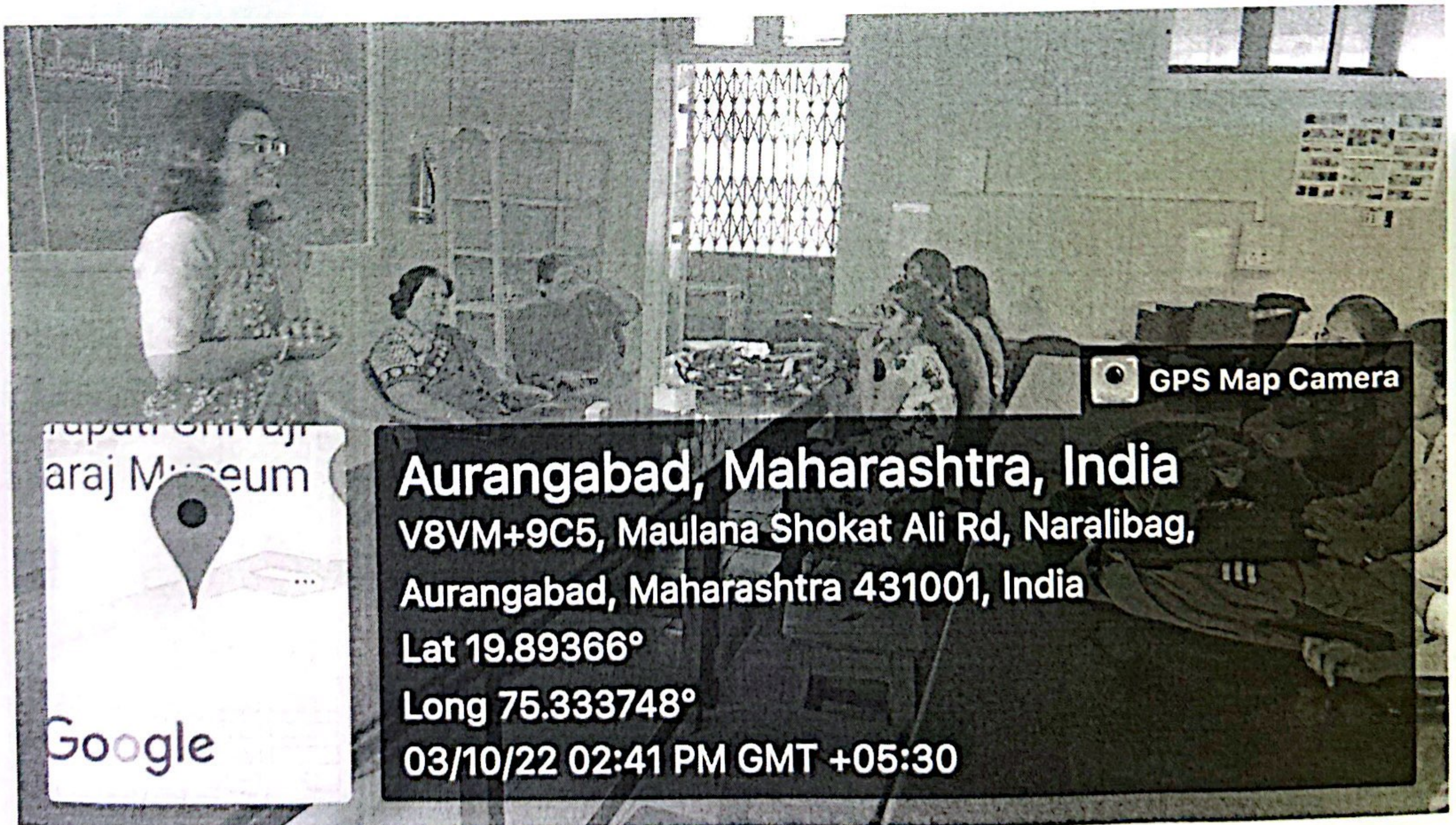
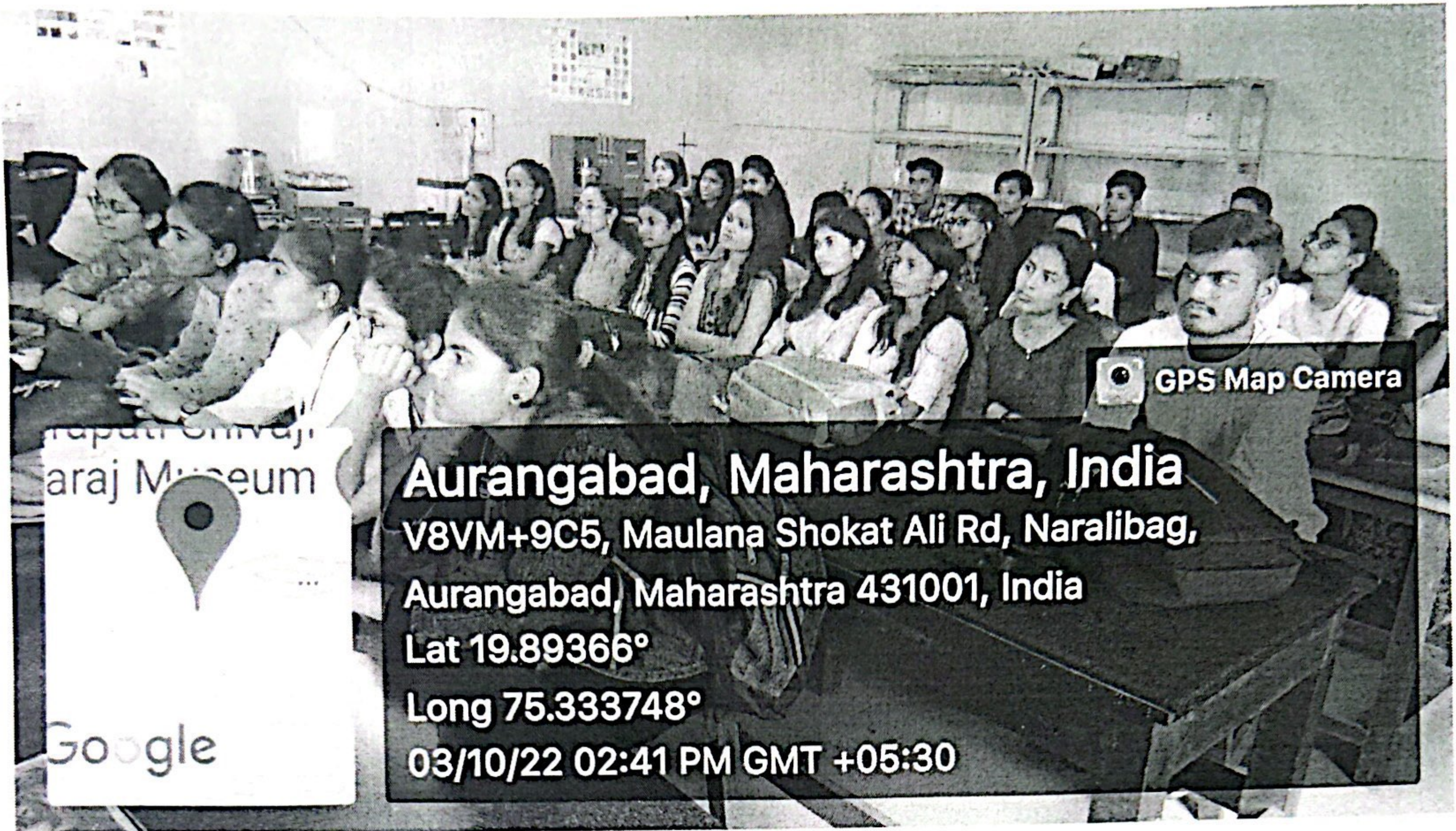
Dept. of Microbiology - G.A.S.S.A.
 Training on "Laboratory skills & Techniques in Microbiology"

Date 3/10/2022
 Time - 2.00 - 5.00 pm.

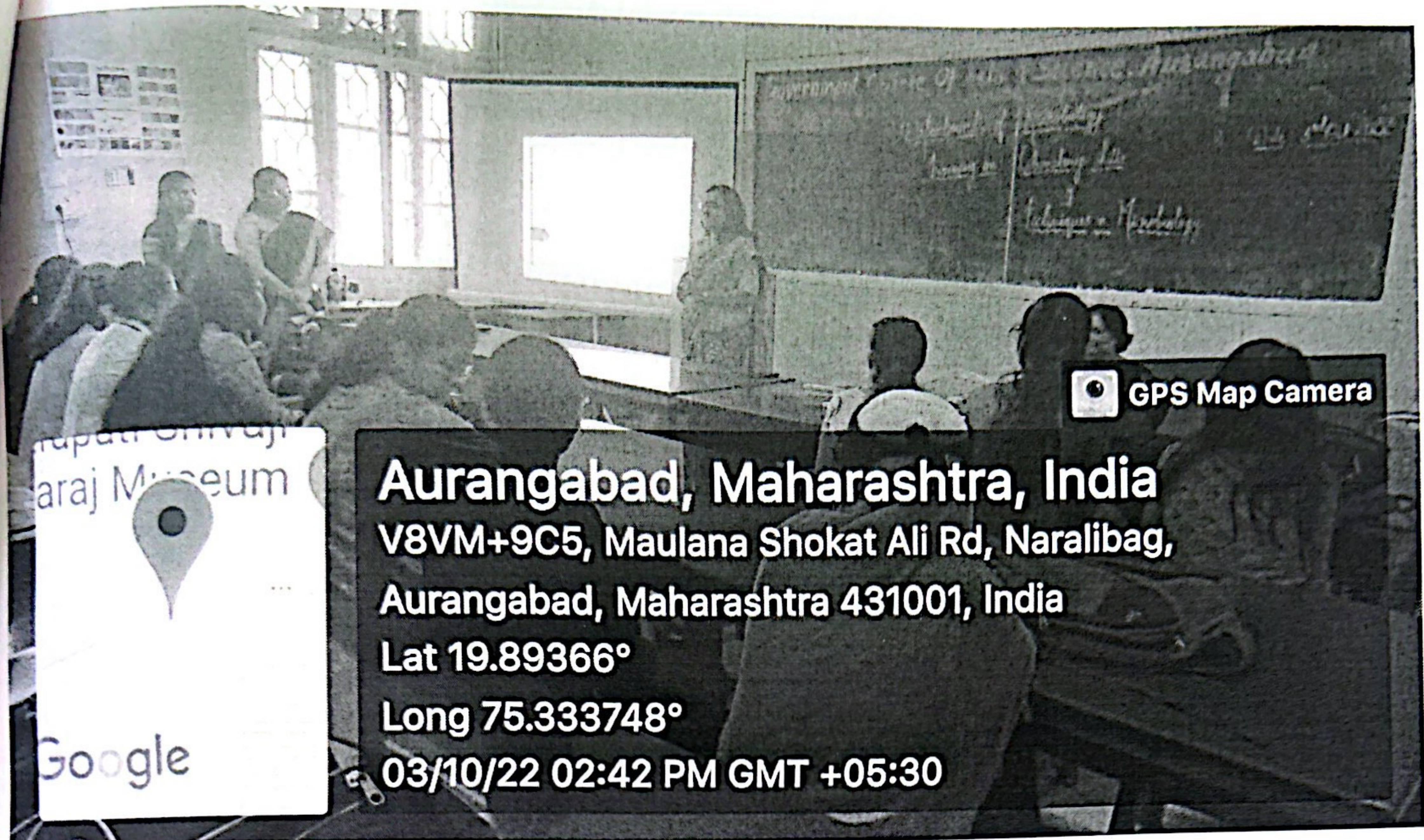
Students Attendance

S. NO	Name	Signature	Year (I, II, III yr)
1.	Vishal Rajendra Bhisane	<u>Vishal Bhisane</u>	(I yr)
2.	AKSHAY Lalzarp	<u>Akshay</u>	(I yr)
3.	Atinoya Siset	<u>Atinoya</u>	(I yr)
4.	ASHISH P. JIVRAO	<u>Ashish</u>	(I st year)
5.	Yogesh Ranbawle	<u>Yogesh</u>	(I st year)
6.	Anjali Dabhade	<u>Anjali</u>	(I st year)
7.	Vaishnavi Ahe	<u>Vaishnavi</u>	(II nd year)
8.	Kaveri Patil	<u>Kaveri</u>	(II nd year)
9.	Nikita Durve	<u>Nikita</u>	(II nd year)
10.	Shreya Jagtap	<u>Shreya</u>	(II nd year)
11.	Hansaja Selinkar	<u>Hansaja</u>	(I st year)
12)	Princa Pawar	<u>Princa</u>	(1 st year)
13)	Dipali B. Kute	<u>Dipali</u>	(1 st year)
14)	Mayuri Pawde	<u>M. Pawde</u>	(1 st year)
15.	Shaikh. Shadmeen	<u>Shadmeen</u>	(I. year)
16)	Arti. R. Patil	<u>Arti</u>	(II nd year)
17]	Aishwarya. D. Wagh	<u>Aishwarya</u>	(III year)
18]	Mansi A. Hulkeri	<u>Mansi</u>	(II year)
19)	Anuja R. Bulbule	<u>Anuja</u>	(III year)
20]	Neha P. Gore	<u>Neha</u>	(III rd year)
21)	Jagouti. R. Shingne	<u>Jagouti</u>	(3 rd yr)

Hands on Training
3rd October 2022



M. H. K. K. K.



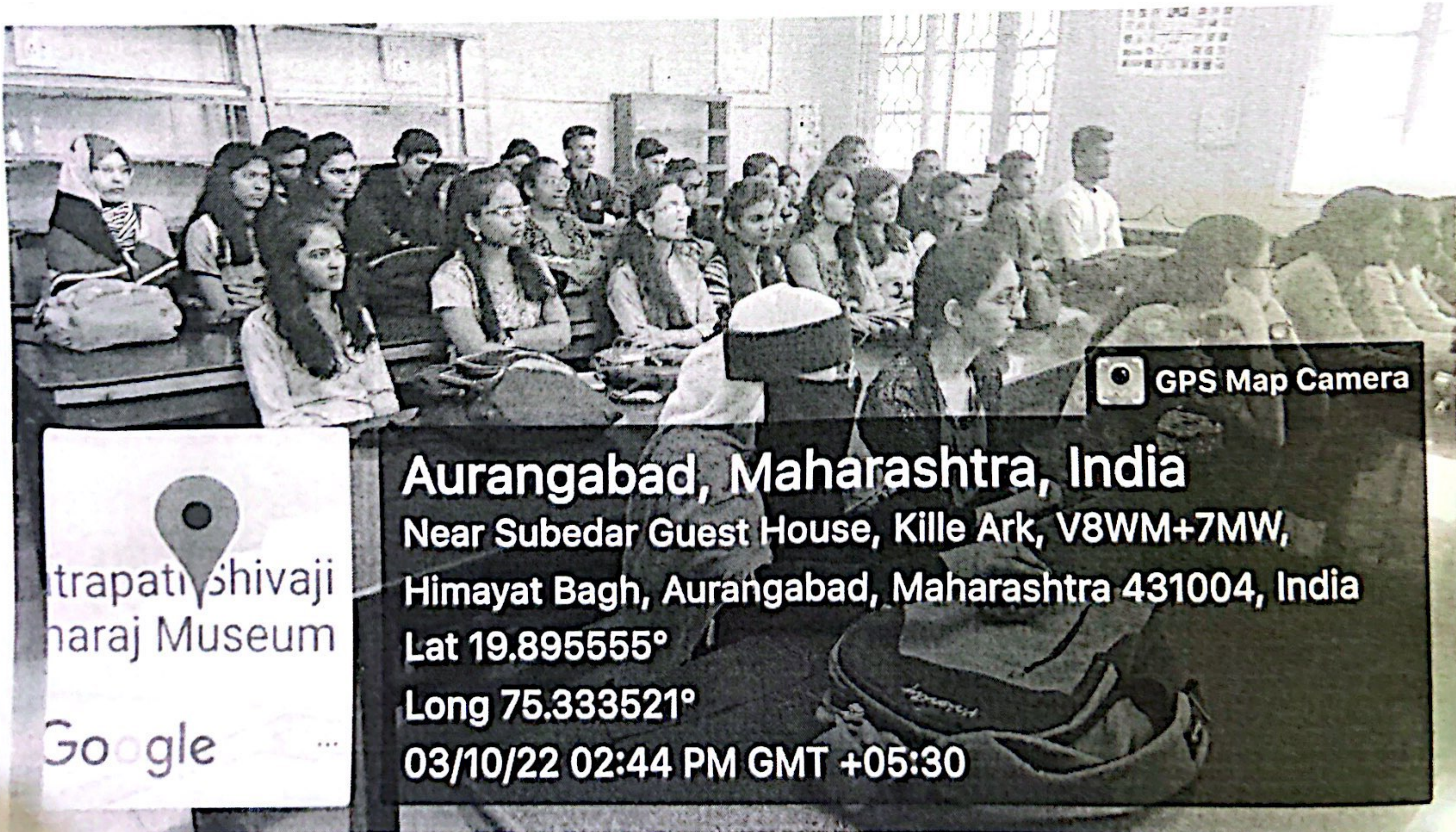
GPS Map Camera

Chhatrapati Shivaji Maharaj Museum




Google

Aurangabad, Maharashtra, India
 V8VM+9C5, Maulana Shokat Ali Rd, Naralibag,
 Aurangabad, Maharashtra 431001, India
 Lat 19.89366°
 Long 75.333748°
 03/10/22 02:42 PM GMT +05:30



GPS Map Camera

Chhatrapati Shivaji Maharaj Museum



Google

Aurangabad, Maharashtra, India
 Near Subedar Guest House, Kille Ark, V8WM+7MW,
 Himayat Bagh, Aurangabad, Maharashtra 431004, India
 Lat 19.895555°
 Long 75.333521°
 03/10/22 02:44 PM GMT +05:30

Rakul Kaur



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GOVERNMENT COLLEGE OF ARTS & SCIENCE,
AURANGABAD

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gasca1923@gmail.com

Fax No. 0240- 2331476

GASCA/2018-19/

Date : 03/09/2018

To.

Dr. Swati Peshwe
Associate Professor
Department of Microbiology
Government Institute of Science,
Aurangabad

Subject-Appreciation letter

Sir.

We are very much thankful to you for accepting the invitation and extending your expertise as a resource person for enlightening our students on **“Cells and Organs of Immune Systems”** in Guest lecture Series in Immunology on 3rd September 2018 in Microbiology Department.

Looking forward for such positive interactions in future.

Thanking you,

Ratulkanni
Principal

Government College of Arts & Science,
Aurangabad



GOVERNMENT COLLEGE OF ARTS & SCIENCE,
AURANGABAD

Department of Microbiology

Guest lecture Series

In

Immunology

By

Dr Swati Peshwe

On

“Cells and Organs of Immune Systems”

3rd September 2018

Sr. no	Student Name	Sign
1.	Pranita Prabhakar Bankar	Bankar
2.	Shubhangi Devidas Kanade	Kanade
3.	Mayuri Sukhadoo falke	Mayuri
4.	Pranjal Dilipkumar Khedkar	Pranjal
5.	Snchal Subhash Pawar	Snchal P.
6.	ISHAVANA BALASAMHEB THORAT.	ISHAVANA
7.	Chaitali Kaduba Gadekar	Chaitali
8.	Poojakta M. Moon	Pmoon
9.	Rani J. Rathod	Rathod
10.	Sayali Ingole	Sayali
11.	Shradha Uballhousele	Shradha
12.	Pratiksha Jankar	Pratiksha
13.	Hemant Shrikhande	Hemant
14.	Akshay Bhalerao	Akshay
15.	Amit Shinde	Amit
16.	Chumble Rangnath G.	Chumble
17.	Gavali prashant vyankat Rao	Gavali



18.	Harsha Suresh Ahende	
19.	Mrunal S. Kanble.	
20.	Shivani K. Shejul	
21.	Shivani P. Adhagale	
22.	Pratik P. Udanshiv.	
23.	Mangesh N. Potole	
24.	Jayesh Suzyawanshi	
25.	Paameshwar S. Lekule	
26.	Sandip R. Sureshe	
27.	Krushna S. Kondke	
28.	Kaṭan K. Chabukswat	
29.	Pratap P. Zinjurde	
30.	Dnyaneshwar Suresh Bhandare	
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HEAVY METAL DETOXIFICATION USING PHYSICO-CHEMICAL AND BIOLOGICAL METHODS: A LITERATURE REVIEW

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ABSTRACT

In the following review an account of the different processes for detoxification of heavy metals has been elaborated. The Physico-chemical methods have been explained with respect to the principle and the process involved. In biological methods both intracellular and extracellular uptake, binding, chelation, biosorption, precipitation, volatilization have been considered. Metal – microbe interaction at the level of cell wall, intracellular accumulation, extracellular interaction have been discussed.

KEYWORDS: Heavy metals, Osmosis, electro dialysis, ion exchange, chemical precipitation, Ultrafiltration, Reduction, Methylation.

INTRODUCTION

Heavy metals released in effluents of many industries is toxic to the ecosystem and thus poses a serious threat to the environment. It has genotoxicity affecting the different life forms and thus the need to neutralize or detoxify it using the different methods at our disposal. An example of this is hexavalent chromium which is more soluble and hence available or mobile in an ecosystem. If it is converted to trivalent chromate, it is precipitated (reduced) out, thus becomes unavailable or immobile. This process of immobilizing chromate can be tried out using a number of physico-chemical or biological methods. In the same manner, mercury can be detoxified using methylation. Similar processes that can control the movement of these metals into different life forms can also result in a check on biomagnifications and its entry into the food chain.

REVIEW OF LITERATURE

Physico-chemical methods involved in detoxification of heavy metals.

Various conventional methods to treat metal pollutants from the effluents are used to control the toxic effect of these metal ions on environmental pollution as well as on various biological systems. The prominent one includes Ion exchange, filtration, precipitation, electrochemical treatment, reduction, chemical reduction, cementation, evaporation recovery (Nyer, 1992). A comparison of various methods used for removal and recovery of metals is given in Table 1 (Iyenger, 2005).

Table 1: Comparison of treatment technologies to remove/recover metals (Iyenger, 2005)

Technology	Description of process	Disadvantage	Relative Cost
Evaporation	Single /multi stage or vapor compression evaporators	Scaling and/ or fouling	High / Commercial
Distillation	Packed column with heating and concentration device	Scaling and / or fouling	Medium / Commercial
Solvent extraction	Standard procedure	Contaminated solvent requires further processing	Moderately high/ commercial
Adsorption	Batch or continuous adsorption	Limited to low concentration	Medium/ commercial
Ion exchange	Synthetic product	Contaminated solvents required pretreatment.	High / commercial
Membrane processes	Standard manufactured units, with appropriate pretreatment facilities to prevent fouling	Separations are imperfect	Medium/ commercial
Electrochemical processes	DC power and plating apparatus	Impurities upset processes	Medium/ commercial
Starch Xanthate processes	Synthetic product	Preparation is tedious	Medium/ Expt
Biosorption	Live or dead microorganisms.	Emerging technology	Low/recently commercial

Reverse osmosis

It is a process in which heavy metals are separated by a semi permeable membrane at a pressure greater than osmotic pressure caused by the dissolved solids in wastewater. During the process a high pressure is applied to the effluent side of the membrane to force solvent molecules through the membrane. As a result, membrane separates solvent from solute, and thus effluent becomes more and more concentrated in solutes which can be collected and then recycled. The literature on various methods including reverse osmosis for removal of heavy metals from wastewater has been reviewed by Fujie *et. al.* (1993). The disadvantage of this method is that it is expensive.

Electro-dialysis

In this process, the ionic components (heavy metals) are separated through the use of semi permeable ion selective membranes. Application of an electric potential between the two electrodes causes a migration of cations and anions towards respective electrodes. Because of the alternate spacing of cation and anion permeable membranes, cells of concentrated and dilute salts are formed. The disadvantage is the formation of metal hydroxides, which clog the membrane (Tiravanti *et. al.* 1996).

Ultra-filtration:

They are pressure driven membrane operations that use porous membranes for the removal of heavy metals. The main disadvantage of this process is the generation of the sludge. Ultra-filtration is the process where membrane is simply used as a filter. Ultra filtration membranes have large pore size and can remove particulates greater than 20 Å. Some recent work has been done with respect to ultra-filtration to remove metals (Lizzi *et. al.*, 1977).

Ion exchange

Ion exchangers are solid materials which are capable of exchanging cations and anions with their surroundings. A cation exchanger contains exchangeable cations, such as metals or protons. In operation, metal ions in solution are preferentially bound to the insoluble matrix, with the concomitant release of protons or other cations. The toxic metal ion is effectively held within the matrix.

In this process, metal ions from dilute solutions are exchanged with ions held by electrostatic forces on the exchange resins. The disadvantage includes high cost and partial removal of certain ions. This physico-chemical method is amongst popular method for the removal of chromium from wastewaters. Commonly used matrix for ion exchange is synthetic organic ion exchange resins. (Gadd and White, 1993).

Chemical precipitation

Precipitation of metals is achieved by the addition of coagulants such as, alum, lime, iron salts and other organic polymers. The large amount of sludge containing toxic compounds produced during the process is the main disadvantage.

Electrochemical methods

Treatment of effluents with electrochemical methods depends on changing the formal oxidation state of effluent constituents. With regards to metals, a change in oxidation state via electron exchange brings about a significant change in properties which can be utilized to detoxify effluents. Both the oxidation and reduction of metals are viable effluent treatments. Furthermore, effluents containing more than one metal are also amenable for cleanup. Under the general umbrella of electrochemical methods for waste minimization, there are three broad categories of processes; direct (sulphite oxidation, electro-deposition, dissolution of scrap); indirect (cementation, electro-cementation, electro-precipitation, sulphide oxidation) and electrochemically driven (electro dialysis, electrosorption, electrochemical ion exchange, electro filtration, electro-osmosis) electrochemical processes (Mohammad *et. al.*, 2003).

In practice electrochemical methods are used mostly for metal recovery in the electroplating industry for effluents which have high metal content like 2000ppm. A simple cell can be used to electrowin the metals with the final effluent concentration of 300ppm. These techniques can be used to recover nickel from acidic and alkaline spent Ni-plating solution (Bershevits *et al.* 1993) recovery of copper from wash water of electroplating industry (Donchenko, 1994), removal of Zinc from waste water by electrode position (Khan and Lutfil, 1993), treatment of wastewater of

galvanizing plant involving the reduction of Cr^{6+} and removal of $\text{Cr}(\text{OH})_3$ with electrolytically generated $\text{Fe}(\text{OH})_2$, recovery of heavy metals from scrap metal pickling wastewater by electrolysis (Huang *et al.*, 1995).

Membranes have applications in electrochemical separation where electro-dialysis is used, it is having higher selectivity for charged particles. This method uses a direct electrical current to transport ions through ion selective membranes. There are two types of ideal membranes:-

- Anionic (permeable to anions and impermeable to cations)
- Cationic (permeable to cations but impermeable to anions)

Precipitation

Precipitation is by far the most common method for dealing with metals-containing waste. Some metal salts are very insoluble; precipitation generates these insoluble salts in the waste stream by the addition of the appropriate counter anion: the precipitate is then filtered off. The anions are usually hydroxide (OH^-), sulfide (S^{2-}) or carbonate (CO_3^{2-}) and metal is usually an alkali or alkaline metal. In most cases the precipitate is lime slurry $\text{Ca}(\text{OH})_2$ which is readily available and inexpensive. Sodium hydroxide can also be used as a solution and generally gives faster precipitation than lime but it is very sensitive to pH and is inefficient at low pH. Carbonates tend to precipitate at lower pH than hydroxides whereas sulphides tend to give complete precipitation with short coagulation time.

The greatest advantage of precipitation is its simplicity; little is needed in terms of extra plant and expertise. The chemicals like lime slurry is abundantly available, generally inexpensive and under correct condition gives reasonable level of clean up. But the disadvantage is that it is unable to treat acidic effluents, it is non selective giving high water content sludge, presence of other salts and organic agents can severely compromise the precipitation efficiency and cannot be used to treat low concentrations of metals (Barkat, M. A., 2011).

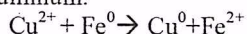
Electro-chemical precipitation

This method utilizes an electrical potential to maximize the removal of heavy metal from contaminated wastewater over the conventional chemical precipitation method (Kurniawan *et al.*, 2006). It is the most common method for removing toxic heavy metals up to (ppm) levels from waste waters.

Although the process is cost effective and its efficiency is affected by low pH and the presence of other salts (ions). The process requires addition of other chemicals, which finally leads to the generation of a high water content sludge, the disposal of which is cost intensive. Precipitation with lime, disulphide or ion exchange lacks the specificity and is ineffective in removal of the metal ions at low concentration.

Cementation

Cementation is a simple metal displacement process used to recover toxic or valuable metals from solution by spontaneous electrochemical reduction to the elemental metallic state, with consequent oxidation of a sacrificial metal by virtue of galvanic cell reaction. A more electropositive metal is used to recover less electropositive metal ion present in the solution. A typical example of this method is the reaction of copper ions with metallic iron. Copper can also be recovered using metallic aluminum.



The process takes place on the surface of Fe, which is anodically dissolved into the solution under open circuit conditions. The advantages of cementation method are the operational simplicity and the use of relatively cheaper reagents.

Solvent extraction

Solvent extraction is a process in which a metal is transferred from aqueous phase to organic phase. The equilibrium stage of this process is termed as liquid partition. One liquid phase is an aqueous solution and the second phase is organic solvent capable of dissolving the distributed at least to certain extent. An extractant is substance with the solvent properties use in a solution of suitable diluents. The main advantages of solvent extraction technique are it is specific with reasonable levels of cleanup upto ppb level, easy modeling and environmentally acceptable alternative to traditional solvent extraction but the disadvantage is it is expensive and requires specialized equipments (Mohammad *et al.*, 2003).

Biological methods

Biological systems have capacity to accumulate metal ions. During growth and metabolism various microorganisms carry out accumulation of various metals, some are essentially required for their metabolic processes. Microbes contain various biochemical processes and efflux processes by which they can deal with different metals. Volatilization is one of the microbial biochemical processes which methylate metals like mercury, selenium, tellurium, arsenic and tin but the processes are complex (Elschenbroich and Salzer, 1992).

Some bacteria have capacity to precipitate metal ions extra-cellularly by the processes of mineralization and the important is by sulfate reducing bacteria, which produce hydrogen sulphide as by product that reacts with metal to produce insoluble metal sulphide. In addition microorganisms possess various mechanisms to accumulate metals intracellularly as well as extracellularly. Extracellular accumulation may be by live cell or by dead biomass. The following table (Table 2) represents comparative performance of various metal recovery technologies.

Table 2: Performance characteristics of heavy metal removal and recovery technologies (Bagdwal *et. al.* 2004)

Technology	Performance Characteristics				
	pH change	Metal sensitivity	Influence of suspended solids	Tolerance to organic molecules	Working level for appropriate metal(mgl ⁻¹)
Adsorption(e.g. Granulated active carbon)	Limited tolerance	Moderate	Fouled	Can be poisoned	<10
Electrochemical	Tolerant	Moderate	Can be engineered to tolerate	Can be accommodated	>10
Ion-exchange	Limited tolerance	Chelate resins can be selective	Fouled	Can be poisoned	<100
Membrane precipitation	Limited	Moderate	Fouled	Intolerant	>10
Hydroxide	Tolerant	Nonselective	Tolerant	Tolerant	>10
Sulphide	Limited tolerance	Limited selectively pH dependent	Tolerant	Tolerant	>10
Solvent extraction	Some system tolerant	Metal-selective extractants available	Fouled	Intolerant	>100

Biological methods used in detoxification of heavy metals:

Metal-Microbes interaction

Industrial activities and deliberate and accidental discharges are the major causes due to which microorganisms are increasingly exposed to toxic levels of metal pollutants and may have to acquire resistance to these metals for their survival, for which they detoxify it by using different mechanisms.

Heavy metals can be accumulated by microbial cells by a variety of processes, both physico-chemical and biological. Metabolism-independent binding or adsorption (biosorption) to living or dead cells, extracellular polysaccharides, capsules and slime layers is frequently rapid. Bacterial cell walls and envelopes and walls of algae, fungi and yeasts are efficient metal biosorbent with binding to charged groups frequently being followed by inorganic deposition of increased amount of metal (Burke *et. al.*, 1991). Volesky (1995) has defined utilization of only dead cells as the basis of biosorption and that of living cells as bioaccumulation. I

In practice there are three categories of biotechnological processes for treating liquid wastes containing toxic metals: biosorption; extracellular precipitation and uptake by purified biopolymers and other specialist molecules derived from microbial cells. These processes are not exclusive and several physico-chemical and biological processes may be involved (Gadd and White, 1993). The below mentioned Table 3 contains a comprehensive data of microorganisms and uptake of heavy metals. (Bagdwal *et. al.* 2004)

Table 3: Examples of metal uptake by microorganisms.

Microorganisms	Metal	Uptake (%dry weight)
<i>Streptomyces sp.</i>	Uranium	2-14
<i>Streptomyces viridochromogenes</i>	Uranium	30
<i>Thiobacillus ferrooxidans</i>	Silver	25
<i>Bacillus cereus</i>	Cadmium	4-9
<i>Zoogloea sp.</i>	Cobalt	25
	Copper	34
	Nickel	13
<i>Citrobacter sp.</i>	Lead	34-40
	Cadmium	170
	Uranium	900
<i>Pseudomonas aeruginosa</i>	Uranium	15
Mixed culture	Silver	32
<i>Chlorella regularis</i>	Uranium	15
<i>Chlorella vulgaris</i>	Gold	10
<i>Phoma sp.</i>	Silver	2
<i>Rhizopus sp.</i>	Cadmium	3
	Lead	10
	Uranium	20
	Thorium	10
<i>Aspergillus niger</i>	Thorium	19
	Uranium	22
<i>Saccheromyces cerevisiae</i>	Uranium	10-15
	Thorium	12

The chemical reaction between microorganisms and metals can be divided into six distinct processes.

a) Intracellular accumulation

Concentration of metals within bacteria and other microbial cells can result from interactions with surface legends followed by slow transport into the cell. This may be an important form of detoxification or a means of incorporating specific metals into enzymes (e. g. Cu and Zn). Extracellular or cell wall attached legends are thought to bind toxic metals. These legends transport the metal complexes through the cell wall in a slow transport step. Metals are released inside the cell, incorporated into biochemical pathways or trapped in an inactive form by complexation with another high affinity legend (Wood and Wang, 1985).

Microbial cells can accumulate inter- cellular both metabolically essential metals, such as Ca, K, Na, Fe, and Mg, as well as non- metabolic metals, such as, Ni, Cd, Co. Intracellular accumulation can be energy dependent function requiring active respiration by the microbial cell. Active metal uptake usually requires a specific transport system. Microorganisms have a well-developed transport systems capable of accumulating metals against gradient. When a metal is taken into the cell, ions of an equivalent charge are released by the cell (Brierly *et. al.*, 1985).

b) Cell wall associated metal binding:

Binding of metals to cell or sorption of metals to living or dead cells is considered a practical solution to many metal contamination problems. Algal surfaces contain functional groups that bind to metals competitively with many dissolved legends. Carboxylic amino, thio, hydroxo and hydroxyl-carboxylic groups on the surface of phytoplankton cells interact co-ordinatively with metal ions (Xue *et. al.*, 1988). Bacteria possess lipopolysaccheride (LPS) in their outer membrane. These chemicals are extremely complex consisting of a hydrophobic, phosphorylated section, known as lipid A, a core oligosaccharide; and variable O-specific side chains consisting of a number of unusual sugars. The side chains project out from the cell membrane and contain different functional groups capable of binding metals. Phosphoryl groups of LPS and phospholipids are the most abundant electronegative sites available for metal binding. The polyvalent toxic metals are primarily bound to LPS molecules because of the presence of closely opposed reactive sites (Ferris, 1989). It has been suggested that this may provide a mechanism to immobilize toxic metals and prevent their entry into the cells.

The membranous structure of the Gram negative cell wall results in a more complex interaction with metals. The outer membrane of *Escherichia coli* K-12 binds to the various metals including Na, Ca, Mg, Sr, Ni, Mn, Pb and Fe.

Approximately 50% of bound metal was usually present in the outer membrane, except for the Mn and Sr. The peptidoglycan layer of Gram negative cell walls also contains sites with which metals can interact. However, the amounts of metal chelated by Gram negative cell walls were less than those chelated by Gram positive cell walls, presumably because the peptidoglycan layer is thinner in Gram negative bacteria and does not contain teichoic acid, a potent chelator of metals (Beveridge, 1981).

Microorganisms can accumulate metabolic and non- metabolic metals by precipitating or binding the metals onto cell walls or cell membranes. Microbial walls are anionic owing to the presence of carboxyl, hydroxyl, phosphoryl, and other negatively charged sites. Cationic metals rapidly bind to these sites by an energy independent reaction. Table 2 comprises the data of metal uptake capacity from effluents by different group of microorganisms.

c) Bacterial cell walls

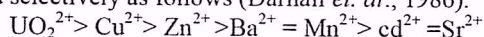
Cell walls of *Bacillus subtilis* are complex polyanion and are likely sites for concentration of metal cations. The isolated cell walls possess select sites, such as diaminopimelic acid residues which retain metals. Isolated cell walls of *Bacillus subtilis* have the greatest preference for Mg, Fe, Cu, Na and K. Lesser amounts of Mn, Zn, Ca, Au and Ni, small amounts of Hg, Sr, Pb and Ag (Beveridge and Murray, 1976).

Fungal cell walls

Like bacteria, both living and non-living fungal biomass can accumulate heavy metals. The uptake of U by *Rhizopus arrhizus* is a three phase process. The first stage involves the formation of a complex between uranyl ions in solution and the nitrogen of the chitin in the fungal wall. In the second stage additional U is absorbed by the three dimensional network of the chitin around the uranyl chitin complex formed in the first stage. In the third stage of the adsorption process the uranyl ion chitin complex hydrolyses precipitating uranyl hydroxide within the chitin network (Sober *et. al.*, 1986).

Algal cell walls

Most of what is known regarding algal metal sorption has been determined from studies of freshwater species of *Chlorella*. However, at least one marine alga (seaweed) has been demonstrated to accumulate significant amount of Co (approximately 17 % of the dry weight present.) and the ability of the eluted (non-living) algal material to resorb additional Co was demonstrated for a total of five complete cycles (Kuyucak and Volesky, 1986). Functional groups in algae and other biomass materials include carboxyl, amide, hydroxyl, phosphate amino, imidazole, thiol and thioether moieties that is present in the proteins, carbohydrates and lipids. Algal genera showing significant metal sorption in the non-viable state include species of *Chlorella reguloris*, *Chlamydomonas* and *Ulthrox*. In decreasing order metals are bound selectively as follows (Darnall *et. al.*, 1986).



d) Siderophores

Siderophores are iron complexing, low molecular weight organic compounds. Two major types are generally considered, the hydroxamate and catecholate. Hydroxamate groups strongly bind to ferric iron. It follows that analogs may also be strongly bound by these siderophores for example aluminum, gallium, and chromium form trivalent metal ions of similar size (Raymond *et. al.* 1984). Molybdenum and copper have been shown to form strong complexes with catecholate siderophores (Hider, 1984).

e) Extracellular processes

Various bacterial metabolites are responsible to cause mobilization or immobilization of metals which has applications in mining and industrial processes. Organic or inorganic acids produced by microorganisms including genera *Thiobacillus*, *Sulfolobus*, *Serratia*, *Pseudomonas*, *Bacillus* and *Aspergillus*, are able to extract metals from solid substrates (Schinner and Burgstaller, 1989).

Extracellular polymer metal interaction

Many microorganisms produce extracellular polysaccharides that strongly bind metals. Metal binding functional group includes pyruvate, phosphate, hydroxyl, succinyl and uronic acid. Bacterial capsules possess features that suggests that they act as effective modulators of metal ion concentration at the cell surface scavenging metals from solution when



their concentrations are low and serving as impermeable barriers when metals exist at toxic levels in the surrounding environment.

Transformation and volatilization of metals

Toxic metal oxides can be used as electron acceptors and the reduced form is frequently less toxic and may be either more volatile or precipitated. Evidence exists that certain metal tolerant bacteria use toxic metal species as electron acceptors, selenate has been shown to be reduced by anaerobic bacteria (Mairers *et. al.*1988). Chromate is also reduced under anaerobic condition and it is associated with a soluble chromate reductase protein (Ishibash *et.al.*1990). Mercury Hg^{2+} is reduced to Hg^0 by mercuric reductase with a subsequent volatilization. A taxonomically diverse group of heterotrophic bacteria utilize metallic cations as terminal electron acceptors under anaerobic conditions. In this process, the metal is reduced to a lower valency which can potentially be utilized in this way by microorganisms. Strain of *Enterobacter cloacae* was isolated from polluted habitat was capable of reducing Cr (VI) To Cr (III) thus reduction of soluble hexavalent chromium to its non soluble trivalent form offers a promising bioremediation strategy (Turick *et. al.*,1998).

Methylation of metalloids

Conversion of inorganic forms of metals or metalloids to methylated forms may be employed by microorganisms as a detoxification mechanism. Some strains of *Penicillium* were shown to methylate selenite and tellurite ions. The metals Hg, Sn, Pl, Pt, Au, the metalloids As, Se, Te, and S have been postulated to accept methyl group from methyl cobalamine in biological system, but not the metals cadmium, lead, and zinc.

Sulphide precipitation

Hydrogen sulphide is produced by sulphate reducing bacteria like *Desulfovibrio* and *Desufotomaculum* sp. The solubility products of most metal sulphides are extremely low and they are readily precipitated as sulphides like ZnS, CdS, and FeS. Sulphate reducing activity can occur as a useful auxiliary metal removing mechanism. Table 4 represents uptake capacities of metals under study by microorganisms.

Table4: Metal uptake capacity by some microorganisms (Bagdwal *et. al.* 2004)

Metal ion	Microorganisms	Metal Uptake Capacity	
		mmol/gm	g/g
Cu	<i>S. cerevisiae</i>	0.68	0.0432
	<i>Rhizopus arrhizus</i>	0.42	0.016
	<i>Chorella fusca</i>	0.05	0.003
	<i>B. subtilis</i>	0.53	0.0033679
	<i>E. coli</i>	0.090	0.005719
Zn	<i>S. cerevisiae</i>	0.47	0.03
	<i>P. chrysogenum</i>	7.83	0.5
	<i>Claviceps paspali</i>	15.30	1.0
	<i>A. niger</i>	0.65	0.042
Cr	<i>R. arrhizus</i>	0.596	0.031
	<i>Candida utilis</i>	0.009	0.0046
	<i>Streptomyces nouresei</i>	0.034	0.0018
Ni	<i>B. subtilis</i>	0.107	0.00628
	<i>E.coli AB264(Envelope)</i>	0.002	0.000117
Mn	<i>B. subtilis</i>	0.801	0.440
	<i>E.coli AB264(Envelope)</i>	0.140	0.00769

CONCLUSION

Thus it is evident from the discussions that these heavy metals can be remediated using various methods. The efficacy of the process would depend on the concentration and type of the heavy metal. The use of physico-chemical methods in metal binding though effective may not be monetarily feasible owing to the higher cost of such materials. In case of biological processes, it may be said that these are in demand as it is a green technology, cheap and is environment friendly. However the selection of the consortium or the pure culture is of utmost importance as metal tolerance and

metal detoxification are two independent characteristics. It has been proved by a number of researchers that organisms that are metal tolerating may not be detoxifying it.

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HEAVY METAL DETOXIFICATION USING PHYSICO-CHEMICAL AND BIOLOGICAL METHODS: A LITERATURE REVIEW

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ABSTRACT

In the following review an account of the different processes for detoxification of heavy metals has been elaborated. The Physico-chemical methods have been explained with respect to the principle and the process involved. In biological methods both intracellular and extracellular uptake, binding, chelation, biosorption, precipitation, volatilization have been considered. Metal – microbe interaction at the level of cell wall, intracellular accumulation, extracellular interaction have been discussed.

KEYWORDS: Heavy metals, Osmosis, electro dialysis, ion exchange, chemical precipitation, Ultrafiltration, Reduction, Methylation.

INTRODUCTION

Heavy metals released in effluents of many industries is toxic to the ecosystem and thus poses a serious threat to the environment. It has genotoxicity affecting the different life forms and thus the need to neutralize or detoxify it using the different methods at our disposal. An example of this is hexavalent chromium which is more soluble and hence available or mobile in an ecosystem. If it is converted to trivalent chromate, it is precipitated (reduced) out, thus becomes unavailable or immobile. This process of immobilizing chromate can be tried out using a number of physico-chemical or biological methods. In the same manner, mercury can be detoxified using methylation. Similar processes that can control the movement of these metals into different life forms can also result in a check on biomagnifications and its entry into the food chain.

REVIEW OF LITERATURE

Physico-chemical methods involved in detoxification of heavy metals.

Various conventional methods to treat metal pollutants from the effluents are used to control the toxic effect of these metal ions on environmental pollution as well as on various biological systems. The prominent one includes Ion exchange, filtration, precipitation, electrochemical treatment, reduction, chemical reduction, cementation, evaporation recovery (Nyer, 1992). A comparison of various methods used for removal and recovery of metals is given in Table 1 (Iyenger, 2005).

Table 1: Comparison of treatment technologies to remove/recover metals (Iyenger, 2005)

Technology	Description of process	Disadvantage	Relative Cost
Evaporation	Single /multi stage or vapor compression evaporators	Scaling and/ or fouling	High / Commercial
Distillation	Packed column with heating and concentration device	Scaling and / or fouling	Medium / Commercial
Solvent extraction	Standard procedure	Contaminated solvent requires further processing	Moderately high/ commercial
Adsorption	Batch or continuous adsorption	Limited to low concentration	Medium/ commercial
Ion exchange	Synthetic product	Contaminated solvents required pretreatment.	High / commercial
Membrane processes	Standard manufactured units, with appropriate pretreatment facilities to prevent fouling	Separations are imperfect	Medium/ commercial
Electrochemical processes	DC power and plating apparatus	Impurities upset processes	Medium/ commercial
Starch Xanthate processes	Synthetic product	Preparation is tedious	Medium/ Expt
Biosorption	Live or dead microorganisms.	Emerging technology	Low/recently commercial

Reverse osmosis

It is a process in which heavy metals are separated by a semi permeable membrane at a pressure greater than osmotic pressure caused by the dissolved solids in wastewater. During the process a high pressure is applied to the effluent side of the membrane to force solvent molecules through the membrane. As a result, membrane separates solvent from solute, and thus effluent becomes more and more concentrated in solutes which can be collected and then recycled. The literature on various methods including reverse osmosis for removal of heavy metals from wastewater has been reviewed by Fujie *et. al.* (1993). The disadvantage of this method is that it is expensive.

Electro-dialysis

In this process, the ionic components (heavy metals) are separated through the use of semi permeable ion selective membranes. Application of an electric potential between the two electrodes causes a migration of cations and anions towards respective electrodes. Because of the alternate spacing of cation and anion permeable membranes, cells of concentrated and dilute salts are formed. The disadvantage is the formation of metal hydroxides, which clog the membrane (Tiravanti *et. al.* 1996).

Ultra-filtration:

They are pressure driven membrane operations that use porous membranes for the removal of heavy metals. The main disadvantage of this process is the generation of the sludge. Ultra-filtration is the process where membrane is simply used as a filter. Ultra filtration membranes have large pore size and can remove particulates greater than 20 \AA^0 . Some recent work has been done with respect to ultra-filtration to remove metals (Lizzi *et. al.*, 1977).

Ion exchange

Ion exchangers are solid materials which are capable of exchanging cations and anions with their surroundings. A cation exchanger contains exchangeable cations, such as metals or protons. In operation, metal ions in solution are preferentially bound to the insoluble matrix, with the concomitant release of protons or other cations. The toxic metal ion is effectively held within the matrix.

In this process, metal ions from dilute solutions are exchanged with ions held by electrostatic forces on the exchange resins. The disadvantage includes high cost and partial removal of certain ions. This physico-chemical method is amongst popular method for the removal of chromium from wastewaters. Commonly used matrix for ion exchange is synthetic organic ion exchange resins. (Gadd and White, 1993).

Chemical precipitation

Precipitation of metals is achieved by the addition of coagulants such as, alum, lime, iron salts and other organic polymers. The large amount of sludge containing toxic compounds produced during the process is the main disadvantage.

Electrochemical methods

Treatment of effluents with electrochemical methods depends on changing the formal oxidation state of effluent constituents. With regards to metals, a change in oxidation state via electron exchange brings about a significant change in properties which can be utilized to detoxify effluents. Both the oxidation and reduction of metals are viable effluent treatments. Furthermore, effluents containing more than one metal are also amenable for cleanup. Under the general umbrella of electrochemical methods for waste minimization, there are three broad categories of processes; direct (sulphite oxidation, electro-deposition, dissolution of scrap); indirect (cementation, electro-cementation, electro-precipitation, sulphide oxidation) and electrochemically driven (electro dialysis, electrosorption, electrochemical ion exchange, electro filtration, electro-osmosis) electrochemical processes (Mohammad *et. al.*, 2003).

In practice electrochemical methods are used mostly for metal recovery in the electroplating industry for effluents which have high metal content like 2000ppm. A simple cell can be used to electrowin the metals with the final effluent concentration of 300ppm. These techniques can be used to recover nickel from acidic and alkaline spent Ni-plating solution (Bershevits *et al.* 1993) recovery of copper from wash water of electroplating industry (Donchenko, 1994), removal of Zinc from waste water by electrode position (Khan and Lutful, 1993), treatment of wastewater of



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galvanizing plant involving the reduction of Cr^{6+} and removal of $\text{Cr}(\text{OH})_3$ with electrolytically generated $\text{Fe}(\text{OH})_2$, recovery of heavy metals from scrap metal pickling wastewater by electrolysis (Huang *et al.*, 1995).

Membranes have applications in electrochemical separation where electro-dialysis is used, it is having higher selectivity for charged particles. This method uses a direct electrical current to transport ions through ion selective membranes. There are two types of ideal membranes:-

- Anionic (permeable to anions and impermeable to cations)
- Cationic (permeable to cations but impermeable to anions)

Precipitation

Precipitation is by far the most common method for dealing with metals-containing waste. Some metal salts are very insoluble; precipitation generates these insoluble salts in the waste stream by the addition of the appropriate counter anion: the precipitate is then filtered off. The anions are usually hydroxide (OH^-), sulfide (S^{2-}) or carbonate (CO_3^{2-}) and metal is usually an alkali or alkaline metal. In most cases the precipitate is lime slurry $\text{Ca}(\text{OH})_2$ which is readily available and inexpensive. Sodium hydroxide can also be used as a solution and generally gives faster precipitation than lime but it is very sensitive to pH and is inefficient at low pH. Carbonates tend to precipitate at lower pH than hydroxides whereas sulphides tend to give complete precipitation with short coagulation time.

The greatest advantage of precipitation is its simplicity; little is needed in terms of extra plant and expertise. The chemicals like lime slurry is abundantly available, generally inexpensive and under correct condition gives reasonable level of clean up. But the disadvantage is that it is unable to treat acidic effluents, it is non selective giving high water content sludge, presence of other salts and organic agents can severely compromise the precipitation efficiency and cannot be used to treat low concentrations of metals (Barkat, M. A., 2011).

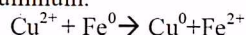
Electro-chemical precipitation

This method utilizes an electrical potential to maximize the removal of heavy metal from contaminated wastewater over the conventional chemical precipitation method (Kurniawan *et al.*, 2006). It is the most common method for removing toxic heavy metals up to (ppm) levels from waste waters.

Although the process is cost effective and its efficiency is affected by low pH and the presence of other salts (ions). The process requires addition of other chemicals, which finally leads to the generation of a high water content sludge, the disposal of which is cost intensive. Precipitation with lime, disulphide or ion exchange lacks the specificity and is ineffective in removal of the metal ions at low concentration.

Cementation

Cementation is a simple metal displacement process used to recover toxic or valuable metals from solution by spontaneous electrochemical reduction to the elemental metallic state, with consequent oxidation of a sacrificial metal by virtue of galvanic cell reaction. A more electropositive metal is used to recover less electropositive metal ion present in the solution. A typical example of this method is the reaction of copper ions with metallic iron. Copper can also be recovered using metallic aluminum.



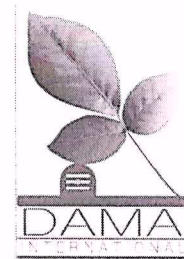
The process takes place on the surface of Fe, which is anodically dissolved into the solution under open circuit conditions. The advantages of cementation method are the operational simplicity and the use of relatively cheaper reagents.

Solvent extraction

Solvent extraction is a process in which a metal is transferred from aqueous phase to organic phase. The equilibrium stage of this process is termed as liquid partition. One liquid phase is an aqueous solution and the second phase is organic solvent capable of dissolving the distributed at least to certain extent. An extractant is substance with the solvent properties use in a solution of suitable diluents. The main advantages of solvent extraction technique are it is specific with reasonable levels of cleanup upto ppb level, easy modeling and environmentally acceptable alternative to traditional solvent extraction but the disadvantage is it is expensive and requires specialized equipments (Mohammad *et al.*, 2003).



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SACCHAROMYCES CEREVISIAE AS A BIOSORBENT FOR DETOXIFICATION OF CR (VI)

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ABSTRACT

Environment pollution is a constant threat faced by humanity. Industrial effluents entering in surface water are one of the most important sources of contamination adding various toxic metals like chromium, cadmium, nickel etc. Microorganisms have great potential to accumulate these metals and detoxify it. Biomass waste, mainly *Saccheromyces cerevisiae* is generated on a large scale from brewing industry which can be used to detoxify metals. In this paper *Saccheromyces cerevisiae* is used as a bioremediator. Microbial cells are used as waste non growing biomass and effect of various parameters affecting biosorption was studied. From the adsorption studies it was observed that *S. cerevisiae* is capable of adsorbing 33mg/gm of hexavalent chromium.

KEYWORDS: Biosorption, *Saccheromyces cerevisiae*, Chromium (VI)

INTRODUCTION

Environmental pollution is a constant threat faced by humanity. Industrial effluents entering into the surface water are one of the most important sources of toxic contamination in the environment. Industries effluent contain heavy metal ions such as chromium, nickel, lead, copper, zinc etc. which interfere with metabolism of living environmental systems. Chromium compounds are extensively used in many industries which include tannery, textiles, metal electroplating, paint and pigment industries that adds Cr (VI) to effluent.

Hexavalent chromium at a concentration of 10g/kg of body weight causes liver necrosis, nephritis and even death in human beings (Dikshit *et.al.* 1989).The properties of heavy metals which warrant their reclamation from effluents are there toxicity and commercial value (Kasam and Baecker,1988) Though the conventional methods such as precipitation, ion exchange, evaporation, reverse osmosis have been reported to effectively treat chromium bearing effluents(Chand *et. al.*, 1994) they are expensive and are especially ineffective when the metal ion concentration in aqueous solution is lower than 50mg/ L. Moreover such treatment produces large amount of sludge to be treated with great difficulties.

Therefore treatment for this waste is important. Microorganisms can remove heavy metal ions from aqueous solution by various mechanisms, which may or may not be related to the metabolic processes of living cells (Norris and Kelly, 1979). In recent years, the process of accumulation of heavy metals by microorganisms was intensely studied. Bacteria, yeast and fungi (Nakajam and Sakaguchi, 1986) as well as algae (Holan *et.al.*, 1993) are being used for metal removal from effluents. Chromium is one of the discharge from the electroplating industries. Hexavalent chromium (Cr⁶⁺) due to its water solubility is toxic to living cells so it is important to remove hexavalent chromium from the effluent. Various physiochemical methods include ion exchange, reverse osmosis, precipitation etc.

One of the most ubiquitous biomass type available for bioremediation of metal is yeast. Yeast retains its removal ability for a broad range of heavy metals. *S. cerevisiae* has proved to be use in bioremediation. It is easy to cultivate on large scale. It can be easily grown by unsophisticated fermentation techniques and inexpensive growth media (Kapoor and Virarghavan, 1995) and yield of the biomass is also high. It is generally regarded as safe. Therefore, biosorbent made from *S. cerevisiae* can be easily accepted by the public when applied practically as sorbent to recover metal ions. *S. cerevisiae* is an ideal model organism to identify the mechanism of biosorption in metal ion removal, especially to investigate the interactions of metal-microbe at molecular level. In this paper growth independent Cr (VI)sorption studies were carried out using *Saccheromyces cerevisiae*.




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MATERIALS AND METHODS

1. *S. cerevisiae* suspension (Absorbance= 1.0 at 600nm)
2. Cr (VI) stock solution (1000ppm) The metal used for the present investigation was potassium dichromate. The stock metal solution was prepared by dissolving 3.735gm of potassium dichromate in 1000ml distilled water which is further diluted.

A. BIOSORPTION OF Cr (VI) :

Optimization of the important parameters using *S. cerevisiae* was carried out with respect to the

1. Initial metal optimization experiments were carried out using 50-500ppm of metal solution in Erlenmeyer flasks to which 1% (W/V) biomass was added, pH was 7.0 incubated at 30°C for 30 minutes on a rotary shaker. After retention the contents were centrifuged at 8000rpm and residual Cr (VI) was analyzed using AAS and percent sorption was calculated.
2. Effect of pH: 100 ml of hexavalent chromium (20ppm) solution with various pH 3,5,7,9 and 11 were used
3. Effect of holding time on percent sorption of 20 ppm Cr(VI) containing metal solution inoculated by 1% biomass (*S. cerevisiae*) was studied by varying the holding time at intervals of 30 minutes.
4. Effect of initial biomass of *S. cerevisiae* was calculated using varying concentration of 1-5% biomass.
5. Effect of various temperature was studied where *S. cerevisiae* (1%) was inoculated in 100ml of hexavalent chromium (20ppm) with pH 7.0 and they were incubated on shaker at various temperatures 10, 20, 30, 40 and 50° c for 3 minutes and analysed for residual chromium

The total Chromium was estimated by using Atomic Absorption Spectrophotometer.

B. ADSORPTION ISOTHERMS AND KINETIC STUDIES:

Adsorption isotherms were applied to the biosorption experiments carried out using *S. cerevisiae* growth independent percent sorption of Cr (VI) with pH 7.0 at 30°C on a rotary shaker at 100 rpm with 1% (w/v) inoculum concentration for varying period of time. In case of growth independent sorption after each 30 minutes results were taken. The data thus obtained was applied to different adsorption isotherms like Langmuir(1918) and Freundlich (1926) and the graphs obtained were as follows.

Kinetics studies were carried out by growth independent Cr (VI) uptake by *S. cerevisiae*. The 1% (w/v) biomass of *S. cerevisiae* was inoculated in 100 ppm Cr (VI) solution with 7.0 pH. It was incubated at 30°C and after each 30 minutes reaction was terminated by centrifugation at 10,000 rpm and the supernatant was analyzed. The percent sorption of Cr (VI) data thus obtained was used for kinetic studies. The Langergen(1998) kinetic model (pseudo first order) and pseudo second order model was studied.

RESULTS AND DISCUSSION:**A. Growth independent percent sorption of Cr (VI) by *S. cerevisiae***

Biosorptive capacity of metal ions was reported to be related to the ratio of the concentration of initial metal ions to the concentration of the biomass. The percent sorption of Cr (VI) by growth independent *S. cerevisiae* was found to be in between the range of 50-70%

Result in Table 1 indicates the effect of initial concentration of Cr (VI) percent sorption of metals. It was observed that maximum Cr (VI) sorption was 67% at 200ppm and 65% at 1% (w/v) of biomass concentration. Vasudevan *et al.*, (2003) found that equilibrium uptake for Cd²⁺ by the protonated yeast was directly proportional to the ratio of the initial metal concentration to the sorbent mass. Therefore, both aspects cannot be neglected when assessing the influence of concentration of the metal ion and the biomass on biosorption, otherwise error would occur (Schiewer and Volesky, 1995).



Table 1 : Effect of initial Cr (VI) concentration on its sorption by *S.cerevisiae*

Initial metal concentration (ppm)	Percent sorption Cr (VI)
50	45
100	54
150	65
200	67
250	66
300	67
350	64
400	61
450	60
500	60

Optimization experiments showed that metal sorption is a rapid process maximum adsorption of Cr (VI) was 92 % after 90 minutes after that it remained constant (Table 2). The biosorption process of heavy metals by *S. cerevisiae* completed rapidly. The biosorption of metal ions of copper, zinc, lead and uranium by non -growing cells of *S. cerevisiae* is a rapid process and often reaches to equilibrium within few hours. Ferraz, *et. al.* (2004) optimized the sorption time for Cr (III) by *S. cerevisiae* from a brewery company in the sorption and desorption process. Results showed that a 30 minute sorption period was the best option to ensure the metal removal from solution and good recovery from biosorbent.

Table 2: Effect of holding time on percent sorption of Cr (VI) by *S.cerevisiae*

Holding time (minutes)	Percent sorption Cr (VI)
30	55
60	88
90	92
120	92
150	92

Table 3: Effect of pH on percent sorption of Cr (VI) by *S.cerevisiae*

pH	Percent sorption Cr (VI)
3.0	12
5.0	15
7.0	65
9.0	46
11.0	18

The sorption of Cr (VI) as a function of pH indicated in Table 3 showed that maximum sorption of Cr (VI) was at pH 7.0. At higher and lower pH values, the percent sorption gradually decreased. The results were similar as that Zn²⁺ adsorption by *Mucor hemilis* and *Penicillium chrysogenum* which gets decreased as pH decreases below 4.0 (Fourest *et.al.*, 1994).



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Table 4 : Effect of temperature (C) on percent sorption of Cr (VI) by *S.cerevisiae*

Temperature	Percent sorption Cr (VI)
10	19
20	45
30	60
40	38
50	14

Adsorption reaction are normally exothermic, so biosorption capacity increases with decrease of temperature (Kapoor and Virarghavan, 1997). In this study 60% of Cr (VI) was adsorbed (Table 4) at 30C. The decrease of active binding sites in the biomass (Ozer and Ozer,2003).

Table 5: Effect of inoculum concentration of *S.cerevisiae* on percent sorption of Cr (VI)

Inoculum level % (w/v)	Percent sorption Cr (VI)
1	51
2	62
3	65
4	68
5	69

Effect of inoculum level of *S. cerevisiae* studies (Table 5) showed that if there was an increase in inoculum level there was also increase in percent sorption of metal ions under study. Initial inoculum level of 2-3 % (v/v) gave maximum percent sorption even if there was an increase in percent sorption there was no significant an increase in percent sorption of Cr (VI).

B. ADSORPTION ISOTHERMS AND KINETIC STUDIES:

In the present study growth independent sorption of Cr (VI) by non-growing *S. cerevisiae* cells is presented in Fig.1 This data is further used to the isotherm calculation (fig.2 and 3). It was observed that in Langmuir isotherm a straight obtained indicating that the data fits in this model. Further the regression coefficient study was carried out which showed 0.99 and that the data fits more in Langmuir isotherm. Hence this data is used to predict the maximum sorption of chromium and from it Qmax for Cr (VI) calculated gave 33mg/gm (Table 6).

Fig 1:Percentage sorption of Cr (VI) by growth independent *S. cerevisiae*

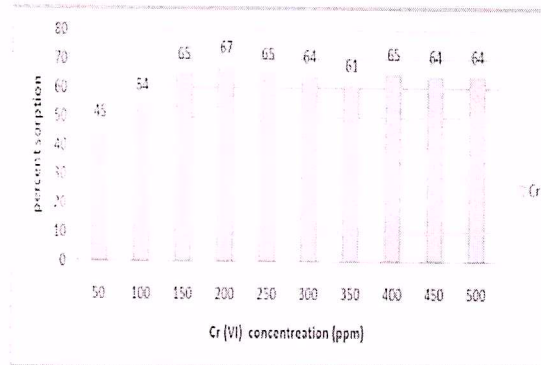


Fig. 2: Adsorption isotherm studies using dead biomass of *S.cerevisiae* (Langmuir)

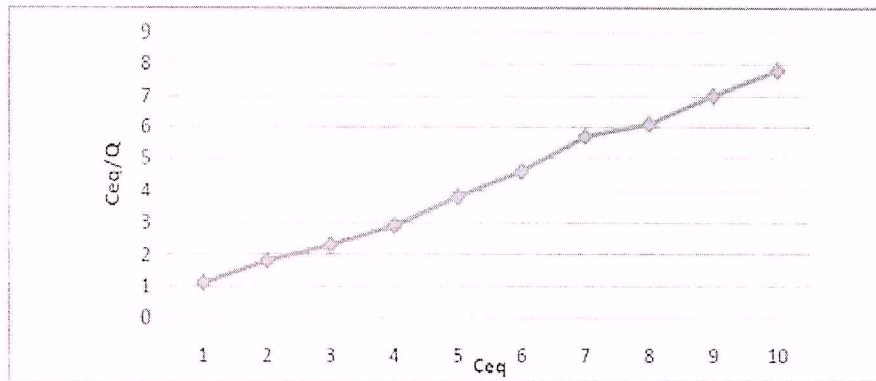


Fig. 3: Adsorption isotherm studies using dead biomass of *S.cerevisiae* (Freundlich)

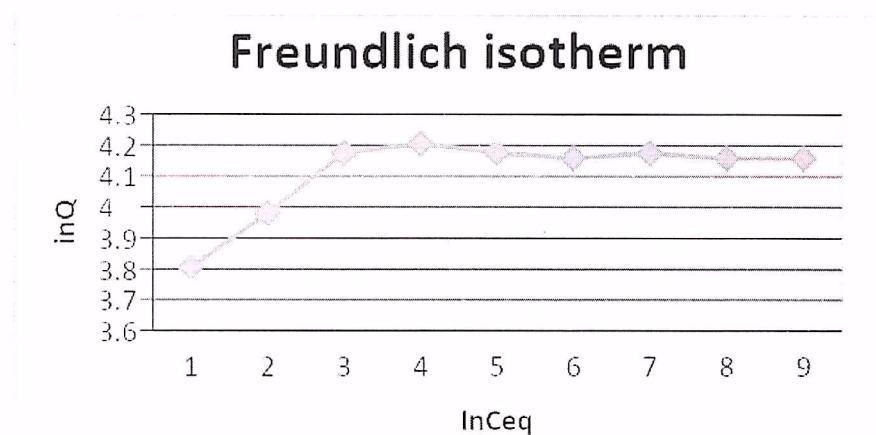


Table 6: Adsorption isotherms parameters for growth independent *S cerevisiae*

Parameters	Langmuir	Freundlich
Slope	0.015139	0.015363
Regression	0.99	0.70
Qmax	33 mg/gm	-

The pseudo first order and second order kinetics model were successfully employed for explaining the kinetic data of adsorption process (Fig.4 and 5) Straight line obtained after plotting Log (qe-qt) vs t and t/qt vs t shows degree of fitness of metal sorption to first and second order rate kinetics model. This is based on the assumption that the adsorption capacity for the metal on the adsorbent is proportional to the number of active sites occupied on the sorbent and metal uptake is by chemisorption. The values of constant of Kd and R² were calculated from the plots (Table 7). From the data obtained Pseudo second order was found to be most suitable for adsorption of Cr (VI).