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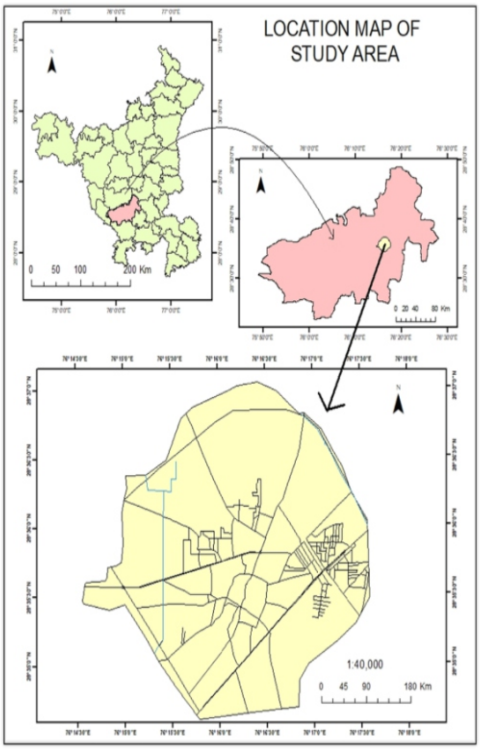

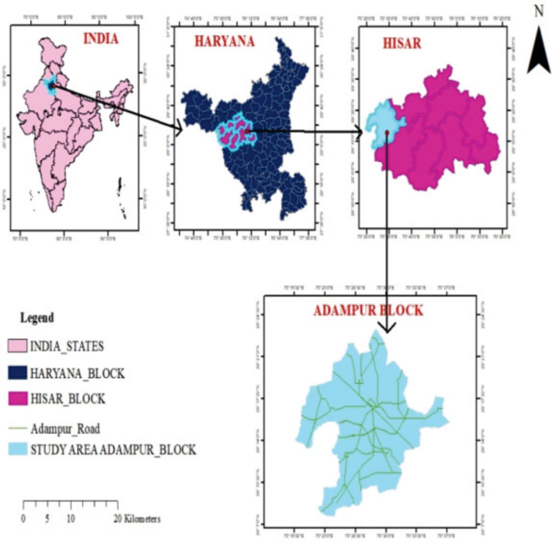


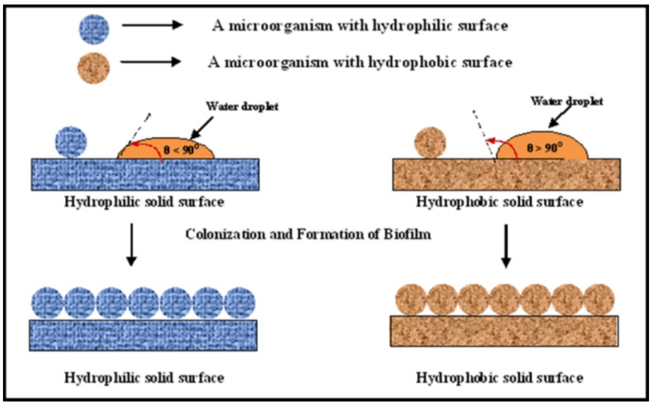

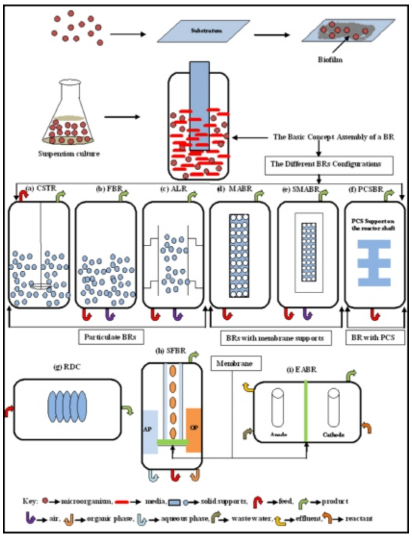


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# INTERNATIONAL JOURNAL OF ENVIRONMENT AND HEALTH SCIENCES

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The IJEHS is an official publication of Save The Environment (STE). It publishes peer reviewed quarterly, original articles (Research paper, Review articles, Short Communication, Case studies, etc.) related to all fields of Environment and Health Sciences. It disseminates the scientific research and recent innovations.

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International Journal of
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## From The Editor's Desk…

As we welcome the New Year 2022, the time has come to work together for creating a sustainable and environment-friendly earth around us by making the most of this recovery phase. New policies are being formulated for improving air, soil and water quality which will further improve the health status of public as well as the environment quotient. Undoing the economic losses and health crisis incurred in the past two years, by implementing more responsible actions will be the main pledge.

One important aspect of the 75th year of Indian independence under 'Azaadi ka Amrit Mahotsav' theme has been designated as repurposing natural compounds for therapeutic functions by harnessing the vast knowledge about traditional medical systems available in our ancient texts. Also, another major focus will be necessitating agricultural reforms in order to reduce gaps in crop production, while ensuring benefits of farmers, who are one of the most important pillars of nation-building.

In view of this, all of us have to act more responsibly by 'life management' such that we move a step closer towards achieving the goal of sustainability, as suggested by The United Nations.

Striving to achieve the aforesaid, The International Journal of Environment and Health Sciences (IJEHS) proposes to provide a reliable platform to discuss relevant technologies and strategies. IJEHS will be quintessential to academicians, industry professionals and researchers who are actively engaged in the areas of environmental issues and related health effects. We are pleased to inform that ISSN for IJEHS is available as 2582-5283. IJEHS is referenced in Crossref, the official Digital Object Identifier Agency (doi 10.47062). IJEHS is now also indexed in the International Scientific Indexing (ISI).

We invite original research articles, short communications and critical reviews directed towards an academic, clinical and industrial audience. The first section of the journal focuses on burning environmental issues like pollutants and their fate, waste management, resource conservation, remediation technologies, etc. The second section includes all topics relevant to physiological impact of environmental risk factors and application of alternative medicinal approaches as remedial measures. Detailed scope can be found in the home page of the journal (www.stenvironment.org/journals). Notes on development of any novel and validated strategy or tool to address environmental challenges are welcome. Discussion on proceedings of conferences conducted on environmental themes and related health aspects will also be considered.

All submissions will be meticulously scrutinized by pioneers in the field to ensure publication of only articles of high quality and relevance. Authors are requested to take special precautions to avert plagiarism and redundancy. It is high time that we realize the gravity of circumstances and take potent steps to undo the adversities already triggered. In this pursuit, IJEHS expects to be the ideal platform to discuss sustainable ideas and potential solutions.

We thank all authors who have contributed to the journal and have consistently been with us in the past years. With this, I wish all our readers a Very Happy New Year, 2022 and I hope our audience and patrons shall come together in this effort to promulgate their part in resurrecting our valuable environment.

**Dr. Kshipra Misra**
Editor-in-Chief, IJEHS

# International Journal of Environment and Health Sciences

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# GROUNDWATER QUALITY ASSESSMENT FOR DRINKING PURPOSE IN CHARKHI DADRI CITY IN HARYANA

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**Abstract**

Water is necessary for survival of living beings. Groundwater is a vital renewable resource. It is 1.7% of the global water quantity. In India, about 90% rural population and 30% urban population depend on groundwater for drinking and domestic requirements. In the present study, groundwater quality has been assessed for drinking purpose in Charkhi Dadri city. Twenty four groundwater samples were collected from different locations in the study area. The collected groundwater samples were analyzed for chemical parameters-pH, TDS, Cl, $HCO_3$, $CO_3$, Mn, Zn, Fe, Mg, Ca and K. The results of chemical analysis of groundwater samples were campared with BIS 10500:2012 drinking water standards. In the study area pH ranges 6.5 to 7.8 and desirable at all the groundwater sample locations, TDS ranges 190 mg/l to 2850 mg/l and non-potable at two sample locations-Near Arvind Hospital (2770 mg/l) and Prem Nagar, Delhi Bypass (2850 mg/l) while desirable at other sample locations in the study area, chloride ranges 10.2 mg/l to 200 mg/l and desirable at all the sample locations, carbonate ranges nil to 0.2 mg/l and desirable at all the sample locations, bicarbonate ranges 0.2 mg/l to 0.7 mg/l and desirable at all the sample locations, total hardness ranges 9 mg/l to 64.5 mg/l and desirable at all the sample locations, calcium ranges 3 mg/l to 21.5 mg/l and desirable at all the sample locations, magnesium ranges 6 mg/l to 43 mg/l and permissible at eight sample locations i.e. Champapuri (35.67 mg/l), Near Ganpati Garden (33.33 mg/l), Shiv Mandir, Main Market (33 mg/l), JVM College Stadium (33.33 mg/l), Easy Day (43 mg/l), Near Municipal Council (38 mg/l), Old Hanuman Mandir (38 mg/l), Gwariya Kua (33 mg/l)while at rest of the sample locations it is desirable, potassium ranges nil to 77.4 mg/l and desirable at all the sample locations, manganese ranges nil to 0.73 mg/l and desirable at Mahendragarh Bypass (nil), Near Jhadu Singh Chowk (0.09 mg/l), Near Bala Wala Mandir (0.03 mg/l), Ram Leela Ground (0.1 mg/l), Gwariya Kua (0.03 mg/l) and permissible at Near Arvind Hospital (0.15 mg/l), Near Loharu Chowk (0.18 mg/l), Near Ganpati Garden (0.12 mg/l), Geeta Bhawan (0.16 mg/l), Near Municipal Council (0.15 mg/l), Mejbaan Hotel Chowk (0.2 mg/l) while non-potable at Prem Nagar, Delhi Bypass (0.31 mg/l), Back side Champa puri (0.63 mg/l), Near Rawaldhi Bypass (0.73 mg/l), Champapuri (0.42 mg/l), Hanuman Mandir,Ghikara Chowk (0.58 mg/l), JVM College Stadium (0.51 mg/l), New Sabji Mandi (0.4 mg/l), Easy Day (0.38 mg/l), Old Shiv Mandir (0.4 mg/l), Kabaddi Market Road (0.42 mg/l), zinc ranges 0.58 mg/l to 7.62 mg/l and desirable in all groundwater samples except at Easy Day (5.12 mg/l), Near Municipal Council (7.62 mg/l), Old Hanuman Mandir (6.21 mg/l) where it is permissible, iron ranges 0.07 mg/l to 0.43 mg/l and desirable in all the groundwater samples except in groundwater samples at JVM College Stadium (0.33 mg/l) and Gwariya Kua (0.43 mg/l) in which it is non-potable. The study is highly useful for planning of groundwater supply for drinking purpose in the study area.

**Keywords**
Groundwater, quality, desirable, permissible, non-potable, Charkhi Dadri, Haryana.

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Color versions of one or more of the figures in this article can be found online at www.stenvironment.org

## INTRODUCTION

Groundwater is the amount of water found below the earth's surface in soil pores and cracks of rocks. As the groundwater is more or less available at all places, it is highly exploitable natural resource. Further, in arid to semi-arid regions of the world, it is the only source of water used for drinking, irrigation and industrial activities. Assessment of groundwater qaulity for drinking purpose is necessary to avoid the ill effects on human health. Many workers (Khazaei et al. (2004), Balakrishnan (2011),Al-Hadithi, Mufid. (2012), Bhatia, A. K., (2012), Kumar, Manjeshand Kumar, Ramesh (2013):, Meride and Bamlakuayenew (2016), Nelly and Mutua (2016)) studied the groundwater quality for drinking purpose in at various locations.

## STUDY AREA

Charkhi Dadri city lies in the southwestern part in Haryana. Chakhi Dadri city is situated between latitudes 28°34'36” N to 28°37'3” N and longitudes 76°14'32”E to 76°17'34” E and covering approximately 14.65 km$^2$ area. Physiographic point of view, Charkhi Dadri is a flat plain area with an average elevation of 213 m.

## OBJECTIVE

The main objective of the study was to assess the groundwater quality for drinking purpose in the study area.

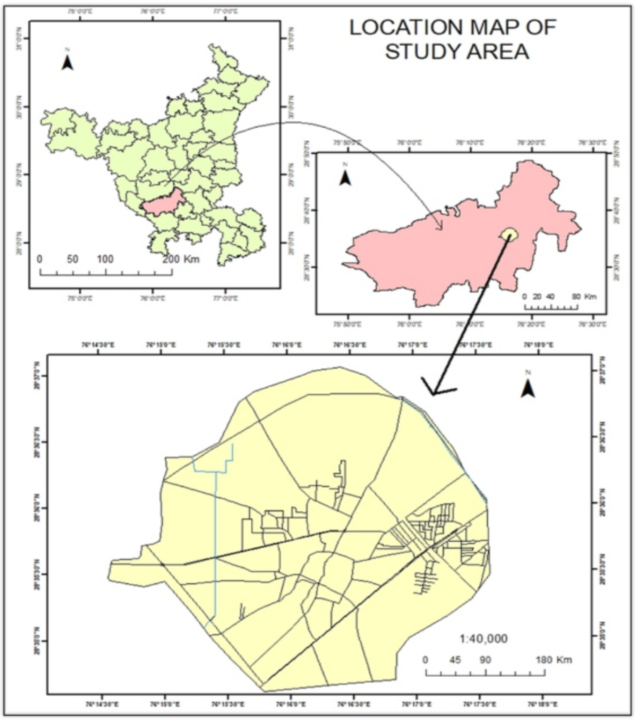


**Fig.1: Location map of the study area.**

## METHODOLOGY

In the study area 24 groundwater samples were collected in 250 ml plastic bottles from different sample sources like hand pump and tube well. Groundwater samples were analysed for pH, total dissolved solids (TDS), chloride (Cl), carbonate ($CO_3$), bicarbonate ($HCO_3$), total hardness (TH), calcium (Ca), magnesium (Mg), potassium (K), manganese (Mn), zinc (Zn) and iron (Fe) (Table 1). BIS 10500:2012 drinking water standards were used to determine the suitability of groundwater samples for drinking purpose (Table 2). Chemical parameter wise bar graphs were prepared to present the scenario of chemical parameter at different groundwater sample locations.

**Table 1: Results of chemical analysis of groundwater samples.**

| Location | pH | TDS (mg/l) | Cl (mg/l) | CO3 (mg/l) | HCO3 (mg/l) | TH (mg/l) | Ca (mg/l) | Mg (mg/l) | K (mg/l) | Mn (mg/l) | Zn (mg/l) | Fe (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Near Arvind Hospital | 6.7 | 2770 | 76.7 | 0 | 0.7 | 34 | 11.33 | 22.67 | 3.7 | 0.15 | 0.58 | 0.12 |
| Prem Nagar, Delhi Bypass | 6.8 | 2850 | 121.5 | 0 | 0.4 | 35 | 11.67 | 23.33 | 3.4 | 0.31 | 0.75 | 0.08 |
| Back side Champa puri | 6.9 | 265 | 59 | 0 | 0.3 | 29 | 9.67 | 19.33 | 77.4 | 0.63 | 0.97 | 0.16 |
| Near Rawaldhi Bypass | 7.2 | 270 | 29.5 | 0 | 0.5 | 26.5 | 8.83 | 17.67 | 2.3 | 0.73 | 1.06 | 0.07 |
| Champapuri | 6.7 | 265 | 89.5 | 0 | 0.3 | 53.5 | 17.83 | 35.67 | 39.6 | 0.42 | 1.24 | 0.16 |
| Hanuman Mandir, Ghikara Chowk | 7 | 245 | 61.5 | 0 | 0.2 | 24 | 8 | 16 | 43.9 | 0.58 | 1.28 | 0.14 |
| Near Loharu Chowk | 7 | 240 | 39.6 | 0.1 | 0.3 | 25.4 | 8.47 | 16.93 | 53.5 | 0.18 | 1.41 | 0.19 |
| Near Ganpati Garden | 6.8 | 255 | 75 | 0 | 0.5 | 50 | 16.67 | 33.33 | 11.4 | 0.12 | 1.54 | 0.04 |
| Aryan Model School | 7.4 | 220 | 14.8 | 0 | 0.4 | 42.5 | 14.17 | 28.33 | 3.5 | 0.3 | 1.71 | 0.1 |
| Shiv Mandir, Main Market | 7 | 230 | 45 | 0.2 | 0.4 | 49.5 | 16.5 | 33 | 61.9 | 0.5 | 1.81 | 0.29 |
| Geeta Bhawan | 6.9 | 260 | 50 | 0 | 0.5 | 24 | 8 | 16 | 8.3 | 0.16 | 1.87 | 0.22 |
| JVM College Stadium | 7.2 | 190 | 200 | 0 | 0.3 | 50 | 16.67 | 33.33 | 1.7 | 0.51 | 1.87 | 0.33 |
| Mahendragarh Bypass | 7.3 | 265 | 10.2 | 0.1 | 0.2 | 12.6 | 4.2 | 8.4 | 0 | 0 | 0.81 | 0.24 |
| New Sabji Mandi | 7 | 195 | 19 | 0 | 0.3 | 9 | 3 | 6 | 6.3 | 0.4 | 2.16 | 0.29 |
| Easy Day | 6.5 | 255 | 46.2 | 0 | 0.4 | 64.5 | 21.5 | 43 | 16.3 | 0.38 | 5.12 | 0.26 |
| Near Municipal Council | 6.8 | 270 | 195 | 0 | 0.6 | 57 | 19 | 38 | 13.5 | 0.15 | 7.62 | 0.27 |
| Old Shiv Mandir | 7.2 | 230 | 25 | 0 | 0.2 | 22 | 7.33 | 14.67 | 6.8 | 0.4 | 2.13 | 0.24 |
| Near Jhadu Singh Chowk | 7.8 | 225 | 48.5 | 0 | 0.3 | 13.7 | 4.56 | 9.13 | 16.8 | 0.09 | 2.14 | 0.25 |
| Old Hanuman Mandir | 6.8 | 260 | 50 | 0 | 0.4 | 57 | 19 | 38 | 29.9 | 0.28 | 6.21 | 0.27 |
| Near Bala Wala Mandir | 7 | 235 | 55 | 0 | 0.2 | 33 | 11 | 22 | 33.6 | 0.03 | 2.29 | 0.25 |
| Kabaddi Market Road | 6.9 | 240 | 41.6 | 0 | 0.3 | 32.5 | 10.83 | 21.67 | 20.6 | 0.42 | 2.21 | 0.21 |
| Ram Leela Ground | 6.9 | 245 | 47 | 0 | 0.3 | 25.5 | 8.5 | 17 | 23.2 | 0.1 | 2.26 | 0.28 |
| Gwariya Kua | 6.4 | 255 | 95 | 0 | 0.2 | 49.5 | 16.5 | 33 | 58.9 | 0.03 | 2.67 | 0.43 |
| Mejbaan Hotel Chowk | 7.6 | 255 | 72 | 0.1 | 0.5 | 16.5 | 5.5 | 11 | 1.3 | 0.2 | 2.31 | 0.28 |

**Table 2: BIS (10500:2012) Drinking Water Standards.**

| S. No. | Characteristics | Desirable | Permissible | Non-Potable |
|---|---|---|---|---|
| 1 | pH | 6.5-8.5 | No relaxation | -- |
| 2 | Total Dissolved Solids (TDS) | <500 ppm | 500-2000 ppm | >2000 ppm |
| 3 | Calcium(Ca) | <75 ppm | 75-200 ppm | >200 ppm |
| 4 | Magnesium(Mg) | <30 ppm | 30-100 ppm | -- |
| 5 | Bicarbonate(HCO3) | <500 ppm | -- | >500 ppm |
| 6 | Potassium(K) | <12 ppm | -- | -- |
| 7 | Iron(Fe) | <0.3 ppm | No relaxation | >0.3 ppm |
| 8 | Manganese(Mn) | <0.1 ppm | 0.1-0.3 ppm | >0.3 ppm |
| 9 | Zinc(Zn) | <5 ppm | 5-15 ppm | >15 ppm |
| 10 | Chloride(Cl) | <250 ppm | 250-1000 ppm | >1000 ppm |
| 11 | Ammonia | <.5 ppm | No relaxation | >.5 ppm |

### I. pH

In the study area pH ranges 6.5 to 7.8. As per BIS 10500: 2012 drinking water standards pH 6.5 to 8.5 is desirable. Hence, in the study area pH is desirable at all the sample locations.

### ii. Total Dissolved Solids (TDS)

In the study area TDS ranges 190 mg/l to 2850 mg/l. As per BIS 10500:2012 drinking water standards TDS is desirable if less than 500 mg/l, permissible 500 mg/l - 2000 mg/l and non-potable if more than 2000 mg/l. TDS is non-potable at two sample locations-Near Arvind Hospital (2770 mg/l) and Prem Nagar, Delhi Bypass (2850 mg/l) while desirable at other sample locations in the study area.

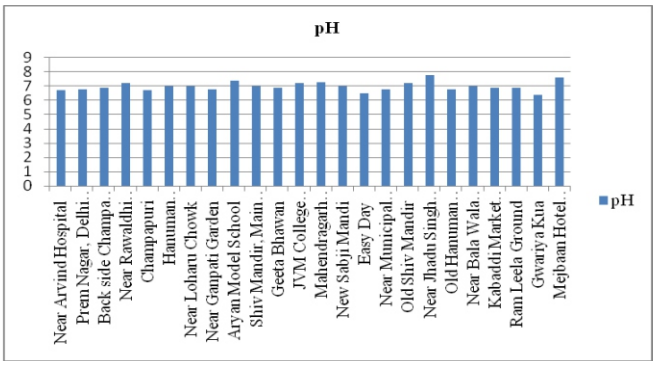


**Fig. 2: Scenario of pH at samples locations in the study area.**

### iii. Chloride

In the study area chloride ranges 10.2 mg/l to 200 mg/l. As per BIS 10500:2012 drinking water standards chloride is desirable if less than 250 mg/l, permissible 250 mg/l - 1000 mg/l and non-potable if more than 1000 mg/l.As per BIS 10500:2012 drinking water standards chloride is desirable at all the sample locations.

### iv. Carbonate

In the study area carbonate ranges nil to 0.2 mg/l. In the study area carbonate has been found in four samples only (Near Loharu Chowk (0.1 mg/l), Shiv Mandir, Main Market (0.2 mg/l), Mahendragarh Bypass (0.1 mg/l), Mejbaan Hotel Chowk (0.1 mg/l). In the study area carbonate is desirable at all the sample locations.

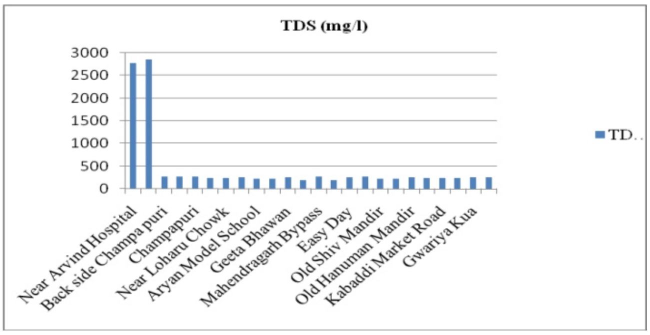


**Fig.3: Scenario of TDS at sample locations in the study area.**

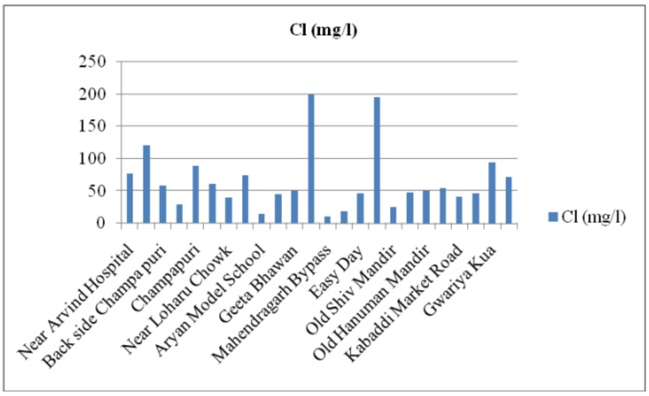


**Fig.4: Scenario of chloride (Cl) at sample locations in the study area.**

### v. Bicarbonate

In the study area bicarbonate ranges 0.2 mg/l to 0.7 mg/l. As per BIS 10500:2012 drinking water standards bicarbonate is desirable if less than 500 mg/l and non-potable if more than 500 mg/l. Thus, in the study area bicarbonate is desirable at all the sample locations.

### vi. Total Hardness

In the study area total hardness ranges 9 mg/l to 64.5 mg/l. As per BIS 10500:2012 drinking water standards total hardness is desirable if less than 200 mg/l, permissible 200 mg/l - 600 mg/l and non-potable if more than 600 mg/l. Thus, in the study area total hardness is desirable at all the sample locations.

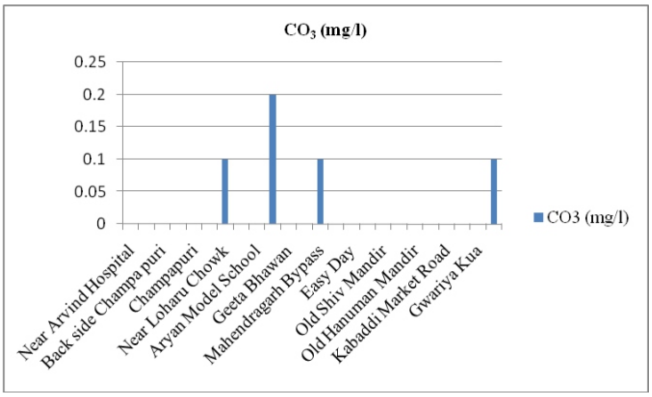


**Fig. 5: Scenario of carbonate at sample locations in the study area.**

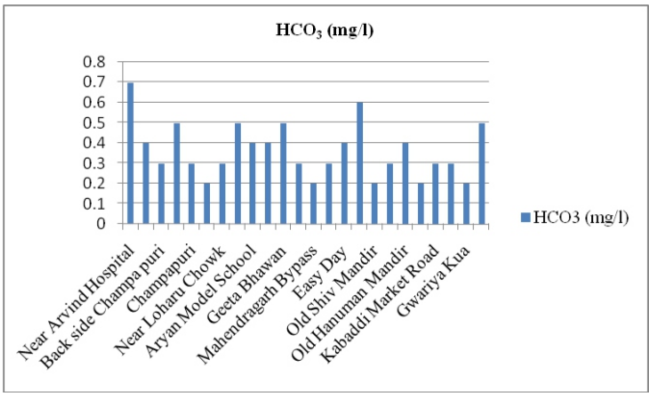


**Fig.6: Scenario of bicarbonate at sample locations in the study area.**

### vii. Calcium

In the study area calcium ranges 3 mg/l to 21.5 mg/l. As per BIS 10500:2012 drinking water standards calcium is desirable if less than 75 mg/l, permissible 75 mg/l - 200 mg/l and non-potable if more than 200 mg/l. Thus, in the study area calcium is desirable at all the sample locations.

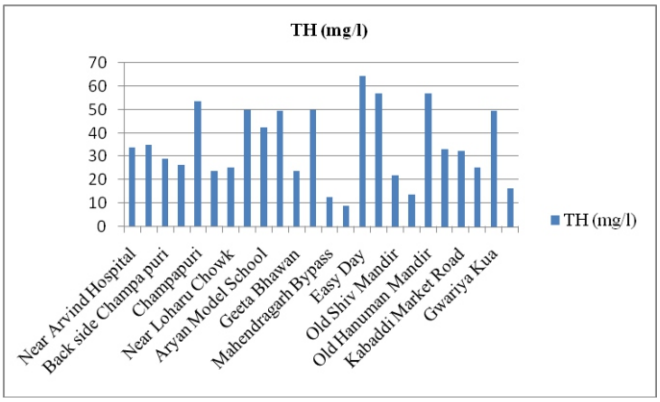


**Fig.7: Scenario of total hardness at sample locations in the study.**

### viii. Magnesium

In the study area magnesium ranges 6 mg/l to 43 mg/l. As per BIS 10500:2012 drinking water standards magnesium is desirable if less than 30 mg/l, permissible 30 mg/l - 100 mg/l and non-potable if more than 100 mg/l. Thus, in the study area magnesium is permissible at eight sample locations i.e. Champapuri (35.67 mg/l), Near Ganpati Garden (33.33 mg/l), Shiv Mandir, Main Market (33 mg/l), JVM College Stadium (33.33 mg/l), Easy Day (43 mg/l), Near Municipal Council (38 mg/l), Old Hanuman Mandir (38 mg/l), Gwariya Kua (33 mg/l) while at rest of the sample locations it is desirable.

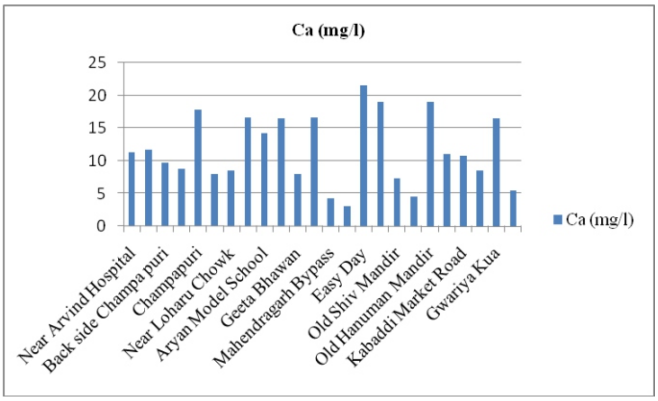


**Fig.8: Scenario of calcium (Ca) at sample locations in the study.**

### ix. Potassium

In the study area potassium ranges nil to 77.4 mg/l. In the study area potassium is desirable at all the sample locations.

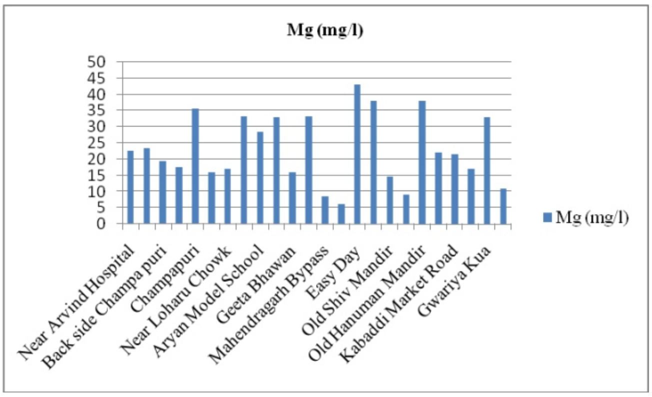


**Fig.9: Scenario of magnesium (Mg) at sample locations in the study.**

### x. Manganese

In the study area manganese ranges nil to 0.73 mg/l. As per BIS 10500:2012 drinking water standards calcium is desirable if less than 0.1 mg/l, permissible 0.1 mg/l- 0.3 mg/l and non-potable if more than 0.3 mg/l. Manganse is desirable at Mahendragarh Bypass ( nil), Near Jhadu Singh Chowk (0.09 mg/l), Near Bala Wala Mandir (0.03 mg/l), Ram Leela Ground (0.1 mg/l), Gwariya Kua (0.03 mg/l) and permissible at Near Arvind Hospital (0.15 mg/l), Near Loharu Chowk (0.18 mg/l), Near Ganpati Garden (0.12 mg/l), Geeta Bhawan (0.16 mg/l), Near Municipal Council (0.15 mg/l), Mejbaan Hotel Chowk (0.2 mg/l) while non-potable at .Prem Nagar, Delhi Bypass (0.31 mg/l), Back side Champa puri (0.63 mg/l), Near Rawaldhi Bypass (0.73 mg/l), Champapuri (0.42 mg/l), Hanuman Mandir,Ghikara Chowk (0.58 mg/l), JVM College Stadium (0.51 mg/l), New Sabji Mandi (0.4 mg/l), Easy Day (0.38 mg/l), Old Shiv Mandir (0.4 mg/l), Kabaddi Market Road (0.42 mg/l).

### xi. Zinc

In the study area zinc ranges 0.58 mg/l to 7.62 mg/l. As per BIS 10500:2012 drinking water standards zinc is desirable if

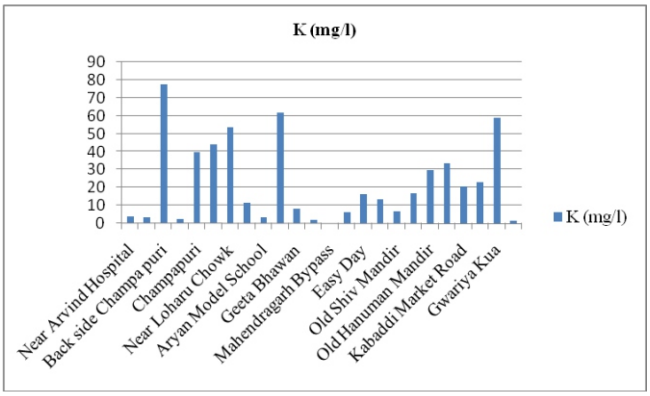


**Fig.10: Scenario of potassium (K) at sample locations in the study.**

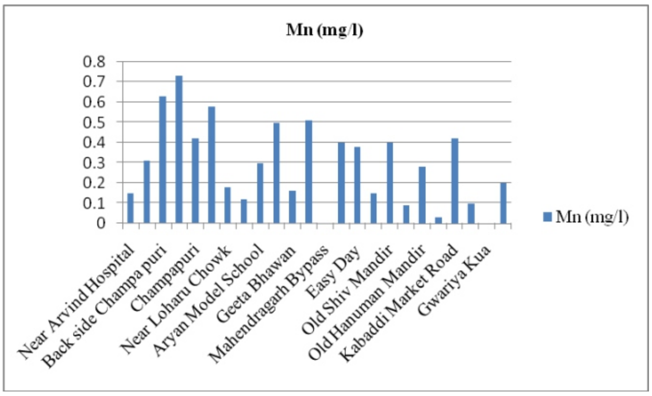


**Fig.11: Scenario of manganese (Mn) at sample locations in the study.**

less than 5 mg/l, permissible between 5 mg/l- 15 mg/l and non-potable if more than 15 mg/l. In the study area zinc is desirable in all groundwater samples except at Easy Day (5.12 mg/l), Near Municipal Council (7.62 mg/l), Old Hanuman Mandir (6.21 mg/l) where it is permissible.

### xii. Iron

In the study area iron ranges 0.07 mg/l to 0.43 mg/l. As per BIS 10500:2012 drinking water standards iron is desirable if less than 0.3 mg/l and non-potable if more than 0.3 mg//. In the study area iron is desirable in all the groundwater samples except in groundwater samples at JVM College Stadium (0.33 mg/l) and Gwariya Kua (0.43 mg/l) in which it is non-potable.

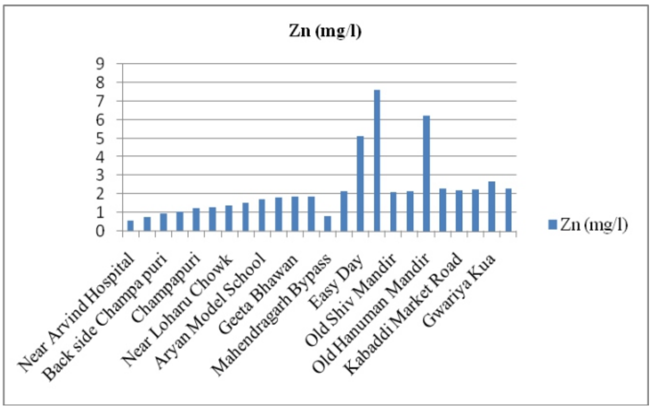


**Fig.11: Scenario of manganese (Mn) at sample locations in the study.**

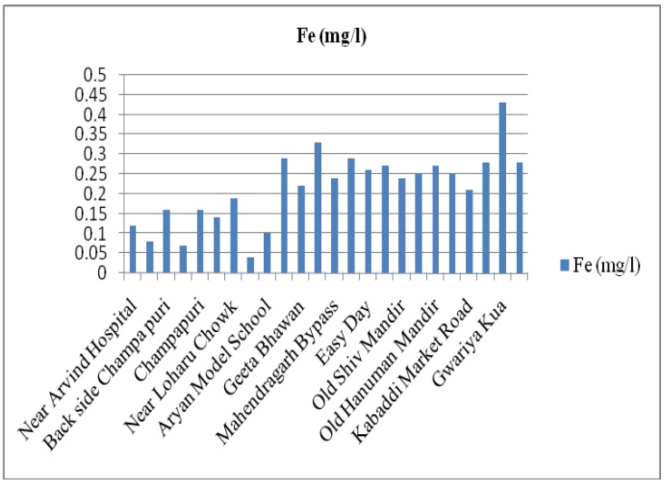


**Fig. 13: Scenario of iron (Fe) at sample locations in the study.**

## CONCLUSIONS

In the study area pH, carbonate, bicarbonate, total hardness, calcium, potassium are desirable. TDS is non-potable at two sample locations-Near Arvind Hospital (2770 mg/l) and Prem Nagar, Delhi Bypass (2850 mg/l) while desirable at other sample locations in the study area.

Magnesium is permissible at eight sample locations i.e. Champapuri (35.67 mg/l), Near Ganpati Garden (33.33 mg/l), Shiv Mandir, Main Market (33 mg/l), JVM College Stadium (33.33 mg/l), Easy Day (43 mg/l), Near Municipal Council (38 mg/l), Old Hanuman Mandir (38 mg/l), Gwariya Kua (33 mg/l) while at rest of the sample locations it is desirable. Manganse is desirable at Mahendragarh Bypass ( nil), Near Jhadu Singh Chowk (0.09 mg/l), Near Bala Wala Mandir (0.03 mg/l), Ram Leela Ground (0.1 mg/l), Gwariya Kua (0.03 mg/l) and permissible at Near Arvind Hospital (0.15 mg/l), Near Loharu Chowk (0.18 mg/l), Near Ganpati Garden (0.12 mg/l), Geeta Bhawan (0.16 mg/l), Near Municipal Council (0.15 mg/l), Mejbaan Hotel Chowk (0.2 mg/l) while non-potable at .Prem Nagar, Delhi Bypass (0.31 mg/l), Back side Champa puri (0.63 mg/l), Near Rawaldhi Bypass (0.73 mg/l), Champapuri (0.42 mg/l), Hanuman Mandir,Ghikara Chowk (0.58 mg/l), JVM College Stadium (0.51 mg/l), New Sabji Mandi (0.4 mg/l), Easy Day (0.38 mg/l), Old Shiv Mandir (0.4 mg/l), Kabaddi Market Road (0.42 mg/l). zinc is desirable in all groundwater samples except at Easy Day (5.12 mg/l), Near Municipal Council (7.62 mg/l), Old Hanuman Mandir (6.21 mg/l) where it is permissible. iron is desirable in all the groundwater samples except in groundwater samples at JVM College Stadium (0.33 mg/l) and Gwariya Kua (0.43 mg/l) in which it is non-potable.

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# ASSESSMENT OF GROUNDWATER QUALITY FOR DRINKING PURPOSE IN ADAMPUR BLOCK, HISAR DISTRICT, HARYANA

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**Abstract**
In arid to semi-arid regions of the world groundwater is the only source for domestic, irrigation and industrial utilisation. In south-western part of Haryana groundwater is the main source for drinking purpose. In the present study groundwater quality has been assessed for drinking purpose in Adampur block in Hisar district of Haryana. In the study area 23 groundwater samples were collected from different locations. Groundwater samples were analysed for chemical parameters of groundwater quality. BIS 10500:2012 drinking water standards were used to assess the suitability of groundwater for drinking purpose. In the study area pH of groundwater samples ranges 6.84 to 8.5 which is desirable, TDS ranges 130 mg/l - 4119 mg/l and desirable at Siswal (130 mg/l), Chuli Kalan (160 mg/l), Mahalsara (260 mg/l), Kabrel (485 mg/l), permissible at Daroli (1440 mg/l), Modakheda (1895 mg/l), Bhodia Kheda (1290 mg/l), Kalirawan (1477 mg/l), Asrawan (1416 mg/l), Adampur Town 3 (1495 mg/l) and non-potable at Near Daroli Minor (3035 mg/l), Dhani Mohbattpur (4445 mg/l), Adampur Town 1 (2019 mg/l), Sadalpur (3539 mg/l), Chibarwal (3773 mg/l), Khairmpur (4082 mg/l), Mothsra (2017 mg/l), Ladwi (4119 mg/l), Kohli (3880 mg/l), Adampur Town 2 (2850 mg/l), Ghudsal (2004 mg/l), Bagla (2019 mg/l). In the study area calcium ranges 2.47 mg/l - 57 mg/l which is desriable in all the groundwater samples. Magnesium ranges 1.2 mg/l - 26.6 mg/l and desirable in all the groundwater samples. Sodium ranges 8.9 mg/l - 80 mg/l and desirable in all the groundwater samples except permssible in groundwater samples at Near Daroli Minor (51.50 mg/l), Dhani Mohbattpur (61.60 mg/l), Chibarwal (74.60 mg/l), Khairmpur (67.60 mg/l), Ladwi (80 mg/l), Kohli (55.90 mg/l). Potassium ranges 2 mg/l - 14.3 mg/l and desiarble in all the groundwater samples except Bhodia Kheda (14.30 mg/l), Adampur Town 3 (13.5 mg/l), Bagla (12.90 mg/l) in which it is non-potabe. Carbonate ranges nil to 0.2 mg/l. In the study area carbonate is desirable in all the groundwater samples. Bicarbonate ranges 15 mg/l - 140 mg/l and desirable in all the groundwater samples. Chloride ranges 1.5 mg/l - 88 mg/l which is desirable in all the groundwater samples. Zinc ranges 0.002 mg/l - 0.33 mg/l and desirable in all the groundwater samples. Iron ranges nil to 0.007 mg/l and desirable in all the groundwater samples.The study is highly useful for planning groundwater for drinking purposes in the study area.

**Keywords**
Groundwater, quality, non-potable, Adampur, Hisar, Haryana.

## INTRODUCTION

Water is a vital natural resource in the world that is required by all living creatures. On the Earth;s surface 71 % is water, of which only 3% of total water is fresh while 97 % is salt water. It makes around 75% of the human body and any shortfall in this amount can be dangerous. Poor water quality can contribute to health problems. Good quality water is beneficial for health and reduce chances of health issues. In arid to semi-arid regions of the world groundwater is the main source for drinking purpose. Assessment of groundwater quality in different types of areas were done by many workers (Malini et al. (2003), Gupta et al. (2009), Kumar and Kumar (2011), Kundu (2012), Sarala and Babu (2012), Goyal (2013), Singha et al. (2015), Asheberom et al. (2016), Bali. and

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Sharma (2016), Dwivedi and Tripathi (2016), Sarita and Rani (2016), Singh et al. (2018), Shamna and Ullas (2020)).

## STUDY AREA

Adampur is a town situated in Hisar district in Haryana. Adampur town is situated at 29.2832°N - 75.43°E. Total geographical area of Adampur block is 367 $km^{2}$. As per Census 2011, population of the Adampur block was 1,46,542. Geomorphologically the study area falls under Indo-Gangetic plain. The entire study area is a nearly flat alluvial plain with minor sand dunes. Climate in the study area is characterized by high temperature and average rainfall.

## OBJECTIVE

The main objective of the study was to study the groundwater quality for drinking purpose in the study area.

## METHODOLOGY

In the study area 23 groundwater samples were collected in 250 ml plastic bottles from different sample sources like hand pump and tube well. Groundwater samples were analysed for pH, total dissolved solids (TDS), chloride (Cl), carbonate (CO3), bicarbonate (HCO3), calcium (Ca), magnesium (Mg), potassium (K), sodium, zinc (Zn) and iron (Fe) (Table 1). BIS 10500:2012 drinking water standards were used to determine the suitability of groundwater samples for drinking purpose (Table 2). Chemical parameter wise bar graphs were prepared to present the scenario of chemical parameter at different groundwater sample locations.

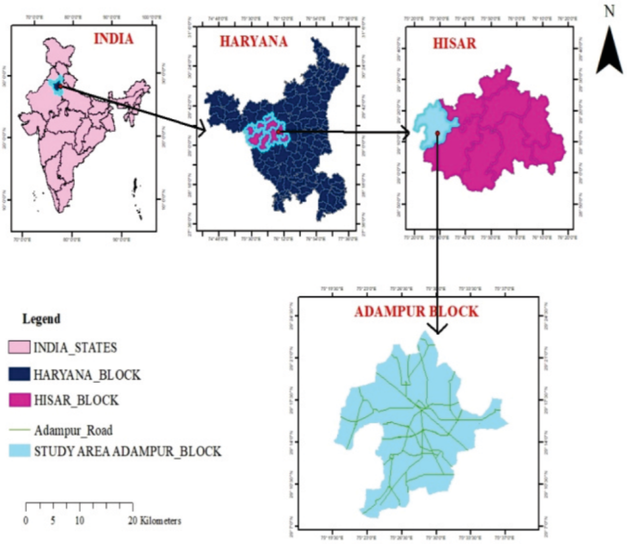


**Fig. 1: Location map of the study area.**

**Table 1: Results of chemical analysis of groundwater samples in the study.**

| S. No. | Sample Location | Latitude | Longitude | Source | pH | TDS (mg/l) | Na (mg/l) | K (mg/l) | Mg (mg/l) | Ca (mg/l) | $CO_3$ (mg/l) | $HCO_3$ (mg/l) | Cl (mg/l) | Zinc (mg/l) | Iron (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Siswal | 29°13'5.86"N | 75°28'50.48"E | Hand pump | 8.50 | 130 | 34.90 | 5.00 | 1.20 | 2.47 | 0.10 | 15 | 2.00 | 0.045 | 0.001 |
| 2 | Daroli | 29°16'29.55"N | 75°24'2.34"E | Hand pump | 7.40 | 1440 | 28.20 | 2.40 | 9.33 | 18.67 | 0.00 | 15 | 2.20 | 0.010 | 0.000 |
| 3 | Chulikalan | 29°15'43.33"N | 75°22'1.59"E | Tube well | 8.10 | 160 | 15.80 | 5.90 | 1.28 | 2.50 | 0.20 | 25 | 1.50 | 0.002 | 0.000 |
| 4 | Near Daroli Minor | 29°15'19.49"N | 75°27'9.78"E | Tube well | 7.10 | 3035 | 51.50 | 2.50 | 16.60 | 33.40 | 0.00 | 40 | 48.00 | 0.011 | 0.000 |
| 5 | Dhani Mohbattpur | 29°13'12.27"N | 75°26'43.05"E | Hand pump | 7.04 | 4445 | 61.60 | 8.30 | 26.60 | 53.40 | 0.00 | 100 | 76.00 | 0.330 | 0.007 |
| 6 | Modakheda | 29°12'59.14"N | 75°25'29.30"E | Hand pump | 7.29 | 1895 | 18.00 | 10.40 | 12.00 | 24.00 | 0.00 | 20 | 36.00 | 0.014 | 0.000 |
| 7 | Adampur Town 1 | 29°16'20.06"N | 75°27'57.99"E | Tube well | 7.20 | 2019 | 32.50 | 2.00 | 14.00 | 28.00 | 0.00 | 40 | 16.00 | 0.006 | 0.000 |
| 8 | Sadalpur | 29°18'45.72"N | 75°26'58.99"E | Tube well | 7.05 | 3539 | 48.40 | 2.30 | 21.30 | 43.00 | 0.00 | 40 | 46.00 | 0.027 | 0.000 |
| 9 | Chibarwal | 29°21'4.67"N | 75°25'57.14"E | Tube well | 7.13 | 3773 | 74.60 | 2.40 | 17.00 | 34.70 | 0.00 | 100 | 64.00 | 0.036 | 0.000 |
| 10 | Bhodia Kheda | 29°21'59.46"N | 75°29'20.09"E | Tube well | 7.20 | 1290 | 20.00 | 14.30 | 12.00 | 25.00 | 0.10 | 60 | 16.00 | 0.046 | 0.002 |
| 11 | Khairmpur | 29°19'11.28"N | 75°31'23.94"E | Tube well | 6.90 | 4082 | 67.60 | 6.00 | 26.00 | 57.00 | 0.00 | 60 | 88.00 | 0.024 | 0.000 |
| 12 | Kalirawan | 29°16'33.12"N | 75°32'51.92"E | Tube well | 7.23 | 1477 | 27.80 | 2.40 | 17.00 | 34.00 | 0.00 | 70 | 32.00 | 0.093 | 0.002 |
| 13 | Asrawan | 29°16'21.43"N | 75°36'0.08"E | Tube well | 7.38 | 1416 | 39.40 | 4.70 | 10.00 | 20.00 | 0.00 | 60 | 12.00 | 0.032 | 0.000 |
| 14 | Mothsra | 29°15'35.71"N | 75°34'12.18"E | Tube well | 7.40 | 2017 | 38.90 | 2.70 | 14.00 | 28.00 | 0.00 | 40 | 16.00 | 0.041 | 0.000 |
| 15 | Ladwi | 29°13'44.76"N | 75°33'2.18"E | Tube well | 7.23 | 4119 | 80.00 | 3.30 | 16.60 | 34.00 | 0.00 | 100 | 30.00 | 0.095 | 0.005 |
| 16 | Mahalsara | 29°15'33.90"N | 75°32'45.64"E | Tube well | 7.67 | 260 | 29.10 | 5.40 | 3.58 | 7.20 | 0.10 | 30 | 2.50 | 0.022 | 0.000 |
| 17 | Kohli | 29°16'57.07"N | 75°31'4.22"E | Tube well | 6.93 | 3880 | 55.90 | 2.00 | 20.10 | 40.00 | 0.00 | 40 | 60.00 | 0.053 | 0.002 |
| 18 | Adampur Town 2 | 29°16'52.83"N | 75°29'0.39"E | Tube well | 7.05 | 2850 | 38.90 | 2.40 | 20.00 | 40.00 | 0.00 | 60 | 5.00 | 0.017 | 0.000 |
| 19 | Khara Barwala | 29°17'48.08"N | 75°27'2.51"E | Tube well | 6.84 | 900 | 8.90 | 8.00 | 6.80 | 14.70 | 0.00 | 90 | 9.00 | 0.048 | 0.000 |
| 20 | Adampur Town 3 | 29°16'59.00"N | 75°27'58.94"E | Tube well | 7.23 | 1495 | 23.30 | 13.50 | 9.16 | 18.30 | 0.00 | 60 | 24.00 | 0.032 | 0.000 |
| 21 | Ghudsal | 29°10'15.79"N | 75°25'36.06"E | Tube well | 7.06 | 2004 | 24.70 | 2.80 | 13.30 | 27.00 | 0.00 | 40 | 34.00 | 0.019 | 0.000 |
| 22 | Bagla | 29°10'53.28"N | 75°30'39.86"E | Tube well | 8.05 | 2019 | 40.50 | 12.90 | 3.00 | 7.00 | 0.20 | 140 | 12.00 | 0.006 | 0.000 |
| 23 | Kabrel | 29°11'20.34"N | 75°28'47.58"E | Tube well | 7.80 | 485 | 36.70 | 7.50 | 5.80 | 11.24 | 0.10 | 50 | 5.50 | 0.008 | 0.000 |

**Table 2: BIS 10500:2012 Drinking Water Standards.**

| S. No. | Characteristics | Desirable | Permissible | Non-Potable |
|---|---|---|---|---|
| 1 | pH | 6.5-8.5 | No relaxation | -- |
| 2 | Total Dissolved Solids (TDS) | <500 mg/l | 500-2000 mg/l | >2000 mg/l |
| 3 | Calcium (Ca) | <75 mg/l | 75-200 mg/l | >200 mg/l |
| 4 | Magnesium (Mg) | <30 mg/l | 30-100 mg/l | - |
| 5 | Bicarbonate (HCO3) | <500 mg/l | - | >500 mg/l |
| 6 | Sodium (Na) | <50 mg/l | 50-200 mg/l | >200 mg/l |
| 7 | Potassium (K) | <12 mg/l | - | - |
| 8 | Iron (Fe) | <0.3 mg/l | No relaxation | >0.3 mg/l |
| 9 | Zinc (Zn) | <5 mg/l | 5-15 mg/l | >15 mg/l |
| 10 | Chloride (Cl) | <250 mg/l | 250-1000 mg/l | >1000 mg/l |

## RESULTS AND DISCUSSION

### i. pH

The pH range of groundwater samples lies between 6.84 to 8.5. As per BIS 10500: 2012 drinking water standards pH 6.5 to 8.5 is desirable. Hence, in the study area pH is desirable at all the sample locations. The highest pH was observed at Siswal (8.5) while lowest pH was observed at Khara Barwala (6.84).

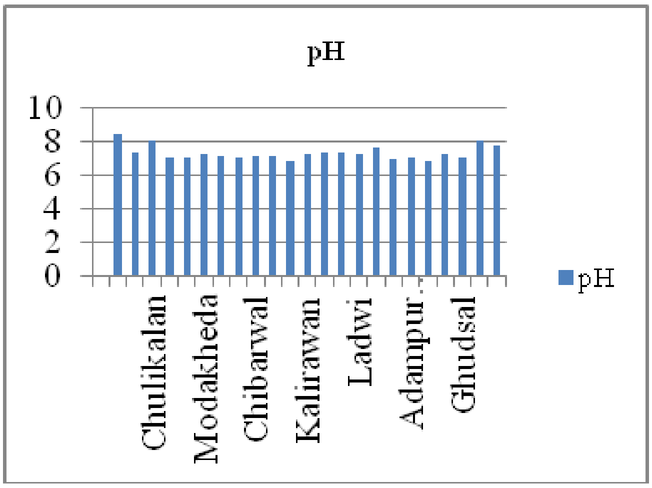


**Fig. 2: Scenario of pH in groundwater samples in the study area.**

### ii. Total Dissolved Solids (TDS)

In the study area TDS ranges 130 mg/l - 4119 mg/l. As per BIS 10500:2012 drinking water standards TDS is desirable if less than 500 mg/l, permissible 500 mg/l - 2000 mg/l and non-potable if more than 2000 mg/l. TDS is desirable at Siswal (130 mg/l), Chuli Kalan (160 mg/l), Mahalsara (260 mg/l), Kabrel (485 mg/l), permissible at Daroli (1440 mg/l), Modakheda (1895 mg/l), Bhodia Kheda (1290 mg/l), Kalirawan (1477 mg/l), Asrawan (1416 mg/l), Adampur Town 3 (1495 mg/l) and non-potable at Near Daroli Minor (3035 mg/l), Dhani Mohbattpur (4445 mg/l), Adampur Town 1 (2019 mg/l), Sadalpur (3539 mg/l), Chibarwal (3773 mg/l), Khairmpur (4082 mg/l), Mothsra (2017 mg/l), Ladwi (4119 mg/l), Kohli (3880 mg/l), Adampur Town 2 (2850 mg/l), Ghudsal (2004 mg/l), Bagla (2019 mg/l).

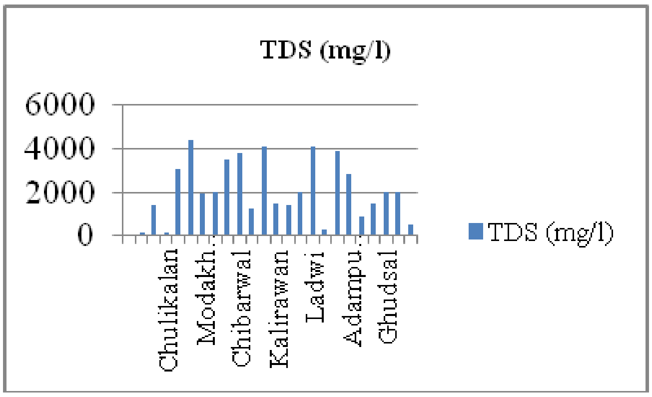


**Fig.3:Scenario of TDS in groundwater samples in the study area.**

### iii. Calcium (Ca)

In the study area calcium ranges 2.47 mg/l - 57 mg/l. As per BIS 10500:2012 drinking water standards calcium is desirable if less than 75 mg/l, permissible 75 mg/l - 200 mg/l and non-potable if more than 200 mg/l. In the study area calcium is desirable in all the groundwater samples.

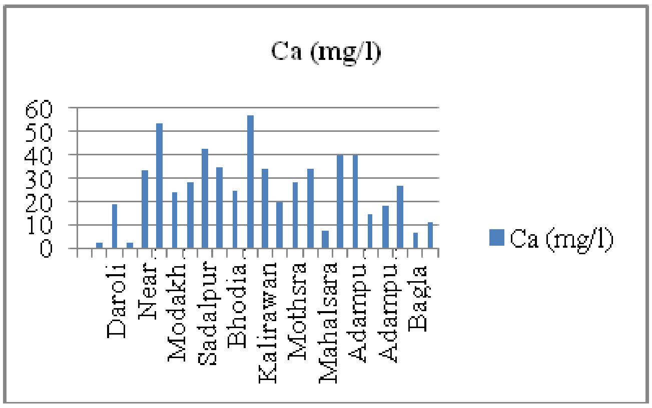


**Fig. 4: Scenario of calcium (Ca) in groundwater samples in the study area.**

### iv. Magnesium (Mg)

In the study area magnesium ranges 1.2 mg/l - 26.6 mg/l. As per BIS 10500:2012 drinking water standards magnesium is desirable if less than 30 mg/l, permissible 30 mg/l - 100 mg/l and non-potable if more than 100 mg/l. In the study area magnesium is desirable in all the groundwater samples.

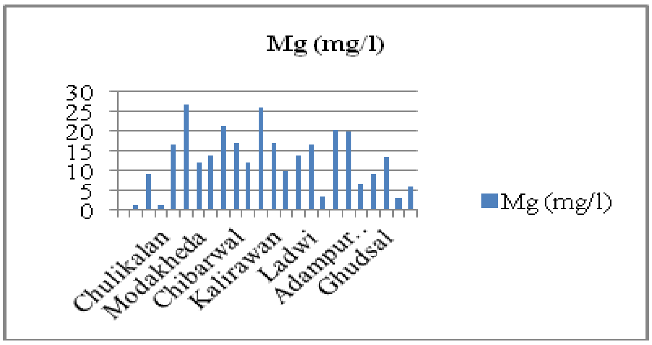


**Fig. 5: Scenario of magnesium (Mg) in groundwater samples in the study area.**

**v. Sodium (Na)**

In the study area sodium ranges 8.9 mg/l -80 mg/l. As per BIS 10500:2012 drinking water standards sodium is desirable if less than 50 mg/l, permissible 50 mg/l - 200 mg/l and non-potable if more than 200 mg/l. In the study area sodium is desirable in all the groundwater samples except permssible in groundwater samples at Near Daroli Minor (51.50 mg/l), Dhani Mohbattpur (61.60 mg/l), Chibarwal (74.60 mg/l), Khairmpur (67.60 mg/l), Ladwi (80 mg/l), Kohli (55.90 mg/l).

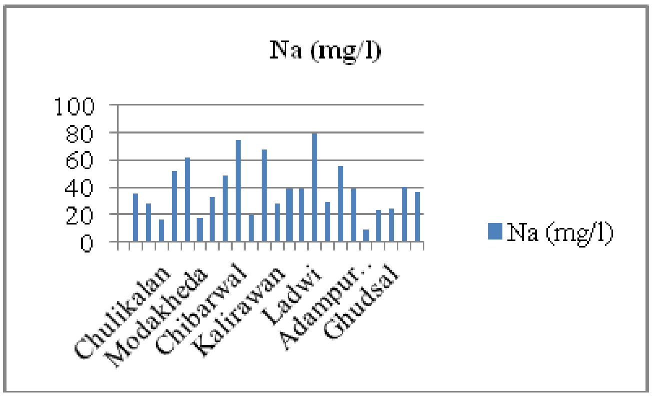


**Fig. 6: Scenario of sodium (Na) in groundwater samples in the study area.**

**vi. Potassium (K)**

In the study area potassium ranges 2 mg/l - 14.3 mg/l. As per BIS 10500:2012 drinking water standards sodium is desirable if less than 12 mg/l and non-potable if more than 12 mg/l. In the study area potassium is desirable in all the groundwater samples except Bhodia Kheda (14.30 mg/l), Adampur Town 3 (13.5 mg/l), Bagla (12.90 mg/l) in which it is non-potable.

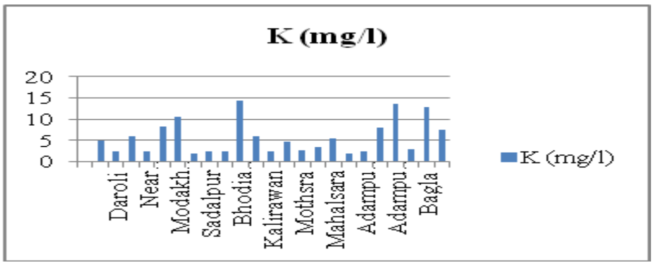


**Fig. 7: Scenario of Potassium (K) in groundwater samples in the study area .**

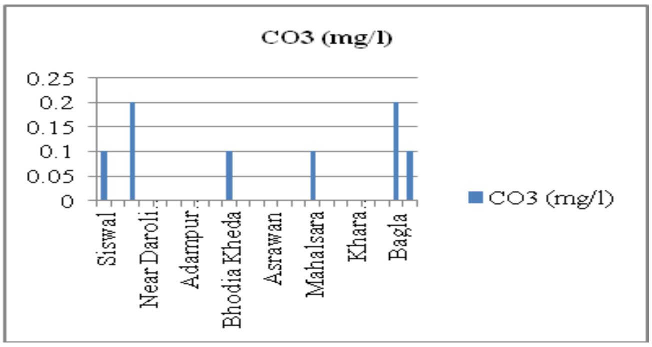


**Fig. 8: Scenario of Carbonate ($CO_3$) in groundwater samples in the study area.**

**vii. Carbonate ($CO_3$)**

In the study area carbonate ranges nil to 0.2 mg/l. In the study area carbonate is desirable in all the groundwater samples.

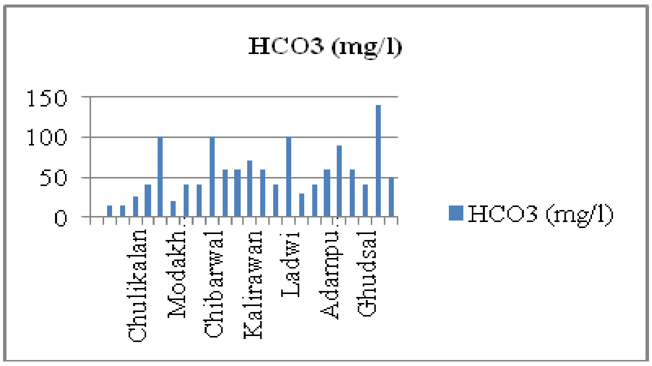


**Fig.9: Scenario of bicarbonate ($HCO_3$) in groundwater samples in the study area.**

**viii. Bicarbonate ($HCO_3$)**

In the study area bicarbonate ranges 15 mg/l - 140 mg/l. As per BIS 10500:2012 drinking water standards bicarbonate is desirable if less than 500 mg/l and non-potable if more than 500 mg/l. In the study area bicarbonate is desirable in all the groundwater samples.

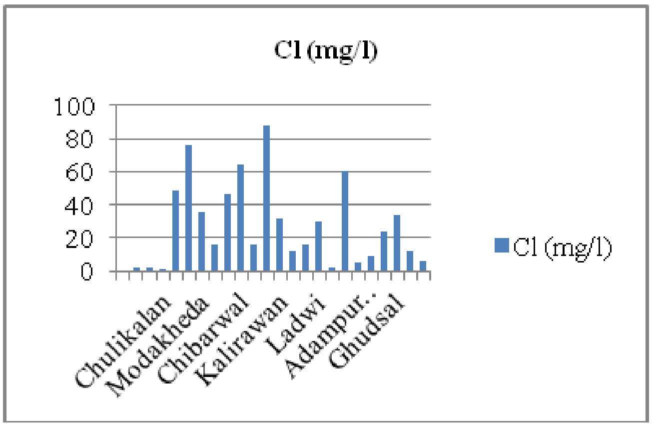


**Fig.10: Scenario of Chloride (Cl) in groundwater samples in the study area.**

**x. Zinc (Zn)**

In the study area zinc ranges 0.002 mg/l - 0.33 mg/l. As per BIS 10500:2012 drinking water standards zinc is desirable if less than 5 mg/l, permissible between 5 mg/l- 15 mg/l and non-potable if more than 15 mg/l. In the study area zinc is desirable in all the groundwater samples.

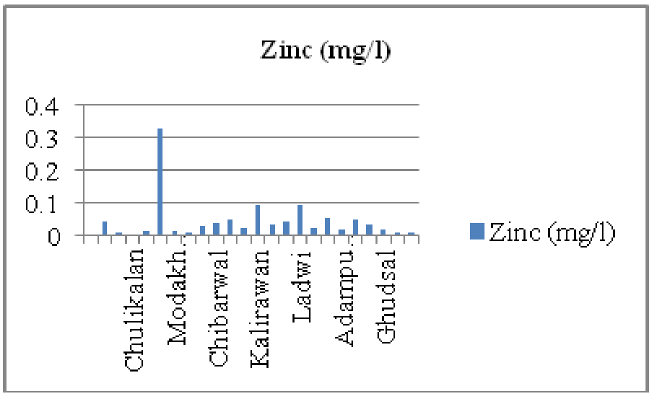


**Fig.11: Scenario of Zinc (Zn) in groundwater samples in the study area .**

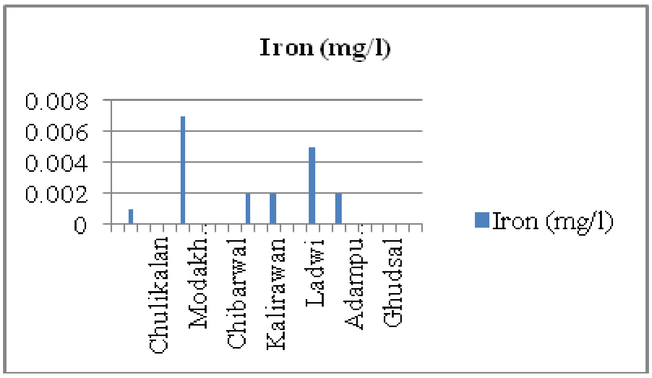


**Fig. 12: Scenario of Iron (Fe) in groundwater samples in the study area.**

**xi. Iron (Fe)**

In the study area iron ranges nil to 0.007 mg/l. As per BIS 10500:2012 drinking water standards iron is desirable if less than 0.3 mg/l and non-potable if more than 0.3 mg//l. In the study area iron is desirable in all the groundwater samples.

## CONCLUSIONS

In the study area pH, calcium, magnesium, carbonate, bicarbonate, chloride, zinc, iron are desirable in all the groundwater samples, TDS is desirable at Siswal (130 mg/l), Chuli Kalan (160 mg/l), Mahalsara (260 mg/l), Kabrel (485 mg/l), permissible at Daroli (1440 mg/l), Modakheda (1895 mg/l), Bhodia Kheda (1290 mg/l), Kalirawan (1477 mg/l), Asrawan (1416 mg/l), Adampur Town 3 (1495 mg/l) and non-potable at Near Daroli Minor (3035 mg/l), Dhani Mohbattpur (4445 mg/l), Adampur Town 1 (2019 mg/l), Sadalpur (3539 mg/l), Chibarwal (3773 mg/l), Khairmpur (4082 mg/l), Mothsra (2017 mg/l), Ladwi (4119 mg/l), Kohli (3880 mg/l), Adampur Town 2 (2850 mg/l), Ghudsal (2004 mg/l), Bagla (2019 mg/l), sodium is desirable in all the groundwater samples except permssible in groundwater samples at Near Daroli Minor (51.50 mg/l), Dhani Mohbattpur (61.60 mg/l), Chibarwal (74.60 mg/l), Khairmpur (67.60 mg/l), Ladwi (80 mg/l), Kohli (55.90 mg/l), potassium is desiarble in all the groundwater samples except Bhodia Kheda (14.30 mg/l), Adampur Town 3 (13.5 mg/l), Bagla (12.90 mg/l) in which it is non-potable. The study is highly useful for planning of groundwater for drinking purpose in the area.

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# BIOLOGICAL PROCESS AND FATE OF CHEMICALS IN INDUSTRIAL WASTEWATER TREATMENT

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**Abstract**
This article will discuss the new and emerging innovative trends in the application of biological processes and fate of chemicals in industrial wastewater treatment. The fate of chemical substances generated after the purification process on a laboratory and industrial scale will also be considered. The article intrusively explores the unique biological aspects of the wastewater treatment process and highlights the advantages they provide for engineering applications in the industries with an approach to chemicals produced during industrial wastewater treatment. Each chapter covers a different biological-based approach and examines the basic principles, practical applications, recent breakthroughs, and associated limitations. It presents an array of cutting-edge wastewater treatment research and thereafter its applications in treatment, remediation, sensing, and pollution prevention processes. The biological process and fate of chemicals for application in wastewater research has a significant impact on maintaining the long-term quality, availability, and viability of water.

**Keywords**
Wastewater treatment, remediation, fate of chemicals.

The short opinion elucidates the technologies of biological wastewater treatment processes of fate of chemicals. The biological processes presented in wastewater treatment processes of fate of chemicals include: (1) bioremediation of wastewater that includes aerobic treatment (oxidation ponds, aeration lagoons, aerobic bioreactors, activated sludge, percolating or trickling filters, biological filters, rotating biological contactors, biological removal of nutrients) and anaerobic treatment (anaerobic bioreactors, anaerobic lagoons); (2) phytoremediation of wastewater that includes constructed wetlands, rhizofiltration, rhizodegradation, phytodegradation, phytoaccumulation, phytotransformation, and hyperaccumulators; and (3) mycoremediation of wastewater. The article describes a broad area of biological processes and water research which are considered key components for advanced water purification. It also includes the desalination technologies that remove, reduce, or neutralize water contaminants that threaten human health and/or ecosystem productivity and integrity. Article is mainly related to each of the main factors contributing to toxic pollutants removal from wastewater, namely, methods and procedures, materials (especially low-cost materials originating from industrial and agricultural waste), management of wastewater containing toxic pollutants, valorization possibilities of waste resulting from the removal of toxic pollutants from wastewater, etc. We also encourage submissions related to recycling, environmental impact, and wastewater policies post-heavy metal removal. This article will focus on the advanced and recent trends in the remediation of toxic pollutants through an approach of environmental processes from either industrial wastewater or sewage wastewater. This article is especially devoted to "Industrial Wastewater Treatment" and aims to present the current state of the art and innovative research that will

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address these challenges, so that wastewater treatment systems can adapt and be fit for purpose, robust, and resilient for the next 100 years. It is equally beneficial for students and professors for understanding the new research advancements in this field.

The main objective of this work was to summarize the work of the eminent scientists in this field in order to provide a clear but concise though that can be used as a quick reference for environmental engineers and researchers, and to be effectively implemented in higher education teaching undergraduate and graduate students, as well as extension and outreach.

# B.
# Health Sciences Section

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# APPLICATION OF BIOFILM REACTOR TECHNOLOGY FOR BIOPRODUCTION: A CLOSER LOOK

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**Abstract**
Applications of customized biofilm reactors have markedly enhanced the productivity of different bioproducts. Implementation of novel concepts in designing of cost effective, durable and commercially scalable substrata has proven their positive impacts on the product features. To make such approaches more generalized in biofilm reactor technology, it is important to highlight the factors that decisively act on the compatibility between microorganisms and solid supports used for different bioproducts. The contents of the review have been strongly oriented towards the broader application of substrata for many bioproducts. Correlations between the variations in the product features and biofilm associated factors have been highlighted. Plastic composite support has been given a special attention. Some of the thermodynamic and interface properties of microorganisms and substrata have been considered. Role of extended Derjaguin, Landau, Verwey, Overbeek theory in assigning the parameters for substrate selection has been discussed. The influence of water structure on the formation of biofilm, and quantitative analysis of physical factors namely adhesion energy, contact angles and primary/secondary minima in selection of substrata have been well addressed. The key issues taken into the consideration and suggestions made in context of the present review can further aid in the customization of biofilm reactor technology.

**Keywords**
Biofilm reactors, plastic composite support, customization, XDLVO theory, adhesion energy, water structure.

## INTRODUCTION

Biofilm reactor (BR) technology has found wider applications in the production of different bioproducts (fine and bulk chemicals, biofuels, organic acids and biomolecules) and wastewater (industrial and municipal origin) treatment processes (Cheng et al., 2010; Qureshi et al., 2005; Wang and Sang, 2009; Straathof et al., 2002; Lazarova and Manem, 1995, 2000; Martin and Nerenberg, 2012). The biological means of wastewater management dates back to 1940, when trickling filters were first introduced at industrial scale in UK (Mishra and Sutton, 1991). In the practice of wastewater engineering, design and operation of trickling filters are now well established (Metcalf and Eddy, 1991). Both fixed- medium system and moving-medium system based BRs have been successfully applied in wastewater treatment for various purposes. In particular, rotating biological contactors (RBC) are the most widely and effectively used moving-medium system type BRs in wastewater treatment (reduction in the level of chemical oxygen demand (COD)/biological oxygen demand (BOD) and nitrification/denitrification) (Kargi and Dincer,1999; Kargi and Ekar, 2001; Gonec and Harremoes, 1985). Since the first commercial-scale application of Biofilm Fluidized Bed (BFB) in the mid-1970s in USA, particulate BRs of different configurations (biofilm upflow sludge blanket, biofilm fluidized bed, expanded granular sludge blanket, biofilm airlift suspension, and internal circulation reactors) have been designed and experimented for lab and large scale wastewater treatment processes in the last two decades (Metcalf and Eddy, 1991). Metabolic efficiencies of different microbial strains has faciliated the use of wide spectrum of cheap and renewable carbohydrate sources in the production of biofuels employing BR technology. Effluents from dairy industries have been utilized as alternative substrates for butanol and acetone-butanol-ethanol production (Jones and Wood, 1986). The newly emerged plastic composite support

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(PCS) technology has successfully designed substrata for biofilm development utilizing agro based waste products (Kunduru and Pometto, 1996). Moreover, industrial waste gases (organic and inorganic) can also be utilized as sources of energy or carbon for microbial metabolism (Ottengraf, 1987).

Novel concepts are being introduced to meet the challenges of limiting parameters of biofilm reactor based production and this has led to the custom designing of BRs (Wood et al., 2001). In addition, extensive molecular study on biofilms of different microbial origin has technically revolutionized the designing of BRs. Concept of designing an air-membrane surface (AMS) bioreactor for the production of secondary metabolites (bacitracin and a red pigment) by *Bacillus licheniformis* strain EI-34-6 is an ideal example of BRs configuration based on molecular aspects of biofilms. The bacitracin molecule played a role of biofilm-specific inducer causing the formation of biofilm at air-membrane interface (Yan et al., 2003).Customization of rotating disc biofilm reactor (RDBR) is another such approach made for *Streptomyces* sp. MS1/7 for the production of antimicrobial compounds (Sarkar and Mukherjee, 2010). The basic outcome of the newly emerged BR technology is the exploitation of microbes for quality enhancement of different products.

However, designing of biofilm reactor and optimization of process parameters seems to be suffering from narrowing down its application. The extent to which the advantages/disadvantages can be generalized for a particular biofilm reactor must be addressed properly. For biofilm forming microbes, change in external stimuli causes drastic physiological, spatial and structural changes of the concerned biofilm. As any alternation in the biofilm directly influences the overall performance of a biofilm reactor, the pros and cons can be predicted for an application of different BRs for a particular product provided that the quality controlling factors are kept optimum. Present review encompasses most of important BR technology based bioproducts for analyzing pros and cons of the contemporary production processes and emphasizes on the need of further customizations and generalizations of the techniques.

## 2. Biofuel

### 2.1. Ethanol

Production of ethanol either with *S. cerevisiae* or *Z. mobilis* in BRs of different configurations has been very productive (Table 2). However, at production and compatibility levels, *Z.mobilis* has proven to be more efficient than *S. cerevisiae*.

#### 2.1.1. Ethanol production and *S.cerevisiae*

The ability to form biofilm by *S.cerevisiae* and its responses under different culture conditions affects productivity of ethanol. In broader sense, adaptability of the yeast to technically different BRs is controlled by all those factors that can cause functional or structural changes of the biofilm. Reynold and Fink (2001) in their investigation on molecular aspects of biofilm formation by *S.cerevisiae*, traced out the key factors influencing the establishment of biofilm on a substratum. These factors and their role in favouring or disfavouring the biofilm formation have been tabulated in Table3. Glucose concentration vs. adherence ability, controlling over expression level of the yeast gene FLO11, role of nitrogen concentration in determining the phenotype (multicellular pseudohyphae or mat type) of biofilm, importance of sliding motility, Ploidy condition and possible exploitation of the mutant strain flo 11 Δ have been well elaborated in the article. This information is important to justify and explain the adoption of a new biofilm reactor technology of ethanol production employing *S.cerevisiae*. Emphasis should be given to sticking to the basic principles of biofilm formation for a microorganism used in fermentative biology while designing a model biofilm reactor.

#### 2.1.2. Ethanol production and *Z.mobilis*

*Z. mobilis* is an ethanologenic and biofilm forming bacterium. Kunduru and Pometto (1996) demonstrated that *Z. mobilis* biofilms could be used in ethanol fermentation [Table 2]. However, formation and morphology of the *Z. mobilis* biofilms were not characterized in this study. The major findings on the different aspects of the biofilm of this bacterium were revealed by Li et al. (2006). They found that *Z. mobilis* cells are capable of forming a biofilm comprised of microcolonies with an average thickness of 20µm embedded in extracellular polysaccharide (EPS) and interspersed with open water channels. The experiment was carried out in a hydrophobically treated 3-mm glass beads packed biofilm reactor. Although the study was undertaken to examine the potential of surface-associated biofilms for biotransformation of chemicals into value-added products and benzyldehyde tolerance taking *Z.mobilis* as model organism, the findings can be implemented for different biofilm reactor based ethanol production. The authors mentioned about the possible role of alternation in gene expression resulting in physiological and/or structural changes during biofilm formation making the biofilm more resistant to benzyldehyde. For ethanol production, *Z.mobilis* has been well exploited using packed bed reactor (PBR), fluidized bed reactor (FBR) and expanded bed BRs [Table 2]. The different substrates used favored the establishment of *Z.mobilis* biofilms. The high ethanol tolerance level enhanced productivity of ethanol in plastic composite support (PCS) and high amenability to genetic manipulation of *Z.mobilis* becomes more understandable if considered as biofilm regulated processes.

### 2.2. Butanol

Compared to ethanol, application of different BRs for the production of butanol using either *Clostridium acetobutylicum* or *Clostridium beijerinckii* is more confined. PBR in particular, has been explored with different substrata resulting in marked variation in the productivities of butanol (Table 4). Bonechar has been found to be the best adsorbent for *C.acetobutylicum*. Due to the high compatibility between the innate properties of the organism and the substratum,

**Table 1: Application and common advantages of conventional and customized BRs in the production of different bioproducts.**

| Biofilm reactor type | Conventional or Customized BR type | Products | Common advantages | Ref |
|---|---|---|---|---|
| Trickling bed reactor (TBR) | Conventional type | Acetic acid, Hydrogen | High cell concentration and productivity. | Kargi and Eker, 1999; Hekmat et al., 2007, Li et al., 2006; Qureshi et al., 2004; Krug and Daugulis, 1983; Qureshi and Maddox, 1987, 1998; Welsh et al., 1987; Zhang et al., 2004; Ho et al., 1997; Urbance et al. 2003, 2004; 33.Weusterbotz et al., Sanroman et al., 1996; Srivastava and Kundu, 1999; Cao et al., 1996; Wang, 2007; Tay and Yang, 2002 |
| Packed bed reactor (PBR) | | Dihydroxyacetone, Benzylalcohol, Ethanol, Butanol, Acetone+butanol, Ethanol+Butanol+Aetone, Poly(3-hydroxubutyrate), Lactic acid, Succinic acid | | |
| Fluidized bed reactor (FBR) | | Ethanol, Citric acid | | |
| Airlift reactor (ALR) | | Cephalosporin C, | | |
| Membrane bed reactor (MBR) | | Cellulose | | |
| Rotating disc contactor (RDC) | | Fumaric acid, Citric acid, Lactic acid, | | |
| Membrane aerated biofilm reactor (MABR) | Customized type | Styrene-oxide | Substrate/product solubility and toxicity can be overcome. | Halan et al., 2010; Gross et al., 2010; Cotton et al., 2001; Cheng et al., 2010; Yang et al., 2003; Sarkar and Mukherjee, 2010; Jeremiasse et al., 2010; Logan et al., 2008; Rabaey et al., 2010; Cheng et al., 2009; 49.Steinbusch, et al., 2010; Nevin et al., 2010. |
| Segmented flow biofilm reactor (SFBR) | | [(S)-styrene oxide] | Direct oxygen transfer, no mass transfer barrier and no excessive biofilm growth. | |
| Solid support membrane-aerated biofilm reactor (SMABR) | | Enantiopure (S)-styrene oxide | High oxygen transfer rate | |
| Plastic composite support biofilm reactor (PCSBR) | | Lactic acid, Bacterial cellulose, Pullulan | Shortened the product formation lag phase | |
| Rotating disc biofilm reactor (RDBR) | | Bacitracin, Other anti-microbial compounds | Highly mimicking of the natural environmental growth conditions | |
| Electro-active biofilm reactor (EABR) | | Biohydrogen, $H_2O_2$, Methane, Ethanol, Caustic soda, multi-carbon organic compounds | Can be combined to a microbial fuel cell (MFC) | |

**Table 2: Performances of different BRs in the production of ethanol.**

| BR type | Year of Reporting | Maximum productivity obtained ($g\ l^{-1}h^{-1}$) | Organism used | Substratum | Ref |
|---|---|---|---|---|---|
| Expanded bed | 1982 | 105 | *Zymomonas mobilis* | Vermiculite | Bland et al., 1982 |
| PBR | 1982 | 28.6 | *Saccharomyces cerevisiae* | Sugarcane bagasse | Tyagi and Ghose, 1982 |
| PBR | 1983 | 27.5 | | Ceramic rods | Chung and Park, 1983 |
| PBR | 1983 | 135.8 | *Zymomonas mobilis* | Resin | Krug and Daugulis, 1983 |
| FBR | 1990 | 100 | | Coke-particles | Dempsey, 1990 |
| PBR | 1996 | 374 | *Zymomonas mobilis* | PCS + 25% various agricultural materials and nutrients | Demirci et al., 1997; Kunduru and Pometto, 1996a, 1996b |
| | | 148 | *Zymomonas mobilis + Streptomyces viridosporus (T7A)* | | |
| | | 190 | *Saccharomyces cerevisiae + Streptomyces viridosporus (T7A)* | | |
| | | 40 | *Saccharomyces cerevisiae* | | |
| PBR | 1997 | 30 | *Saccharomyces cerevisiae* | PCS + 50% various agricultural materials and nutrients | |
| FBR | 2004 | 2.21(continuous) 0.28-0.90 (batch) | *Escherichia coli FBR-5* | Clay brick particles | Qureshi et al., 2004 |
| EABR | 2010 | | Mixed cultures | | [50] |

**Table 3: *Saccharomyces cerevisiae* associated molecular factors influencing the production of ethanol and also showing the probabilities on the application of different BR types.**

| BR type | Use for ethanol production | Comments | Fundamental factors affecting the biofilm formation by *Saccharomyces cerevisiae.* | Ref |
|---|---|---|---|---|
| TBR | Not used. | May be used, as the nutrient deficient may induce phenotypic changes in the biofilm. | **1. Glucose concentration:** Low glucose concentration favors adherence to plastic surfaces like polystyrene, polypropylene and polyvinylchloride. Complete absence of glucose retards the adherence.<br>**2. Genetic factors:** (a) FLO11, a gene required for the production of a cell surface glycoprotein (Flo11p) which helps in both filamentous growth (multicellular pseudohyphae) and mat formation. Flo11p favours hydrophobicity.<br>(b) FLO8, a gene that encodes a regulatory protein required for FLO11 expression.<br>**3. Ploidy condition**: Haploid and Diploid cells do not adhere to plastic supports, but round yeast-form cells do only.<br>**4. Nitrogen Concentration**: *S. cerevisiae* switch from round yeast-form to filamentous growth under nitrogen starved condition.<br>**5. Sliding Motility**: Required for reduced friction between the cells and the substrate thus increases hydrophobicity. Expression level of Flo11p controls the phenomenon.<br>**6. Mutant Strain:** flo 11 Δ is an isogenic strain lacking FLO11 gene. It prefers hydrophilic surface for adherence. | Renolds and Fink, 2001. |
| PBR | Mostly used. | Hydrophobicity and sliding motility favored the biofilm formation | | |
| FBR | Used. | More surface area on the used particles helped in better adherence | | |
| ALR | Not used. | Difficulties may arise in maintaining the sliding motility and hydrophobicity is not favoured | | |
| MBR | | Hydrophilic as well as hydrophobic membranes can support the growth and thus biofilm formation. | | |
| RDC | Not used. | Hydrophilicity is favored so the mutant strain **flo 11** Δ can be employed. | | |
| MABR | | Not preferred for anaerobic processes. | | |
| SFBR | | | | |
| SMABR | | | | |
| PCSBR | Used. | Polypropylene supported the biofilm formation. | | |
| RDBR | Not used. | Not preferred for anaerobic processes. | | |
| EABR | Used | Electrode surfaces (anode/cathode) supported the biofilm formation. | | |

**Table 4: Production summary of butanol obtained with different BRs, employing *Clostridium acetobutylicum* or *Clostridium beijerinckii* and justification for their respective performances.**

| Organism used | BR type | Substratum | Productivity ($gL^{-1}h^{-1}$) | Comments | Ref |
|---|---|---|---|---|---|
| C.*acetobutylicum* | PBR | Beechwood shavings | 1.53 | Control over substratum roughness, hydrophobicity, porosity and expression level of the cell surface protein moieties rich in hydrophobic amino acids can further enhance the productivity. | Qureshi et al., 2005; Qureshi and Maddox, 1987; Welsh et al., 1987; Napoli et al., 2010; Forberg and Haggstrom, 1985 |
| | | Whey permeate | 4.5 | | |
| | | Coke | 1.2 | | |
| | | Bonechar | 6.5 | | |
| | | Glass beads | 0.93 | | |
| | | Glass wool | 0.30 | | |
| | | Polypropylene tow | 0.58 | | |
| | | Stainless steel wire balls | 0.15 | | |
| | | Tygon® rings | 4.4 | | |
| | Membrane cell reactors | | 6.5 | | |
| | FBR | | 1.65 | Hydrophobicity and large surface area of the particles favored formation of the biofilm. | Qureshi et al., 2000 |
| *C. beijerinckii* | PBR | Clay brick | 15.8 | | |

**Table 5: Performances of different microorganisms, substrata and BRs used in the production of different organic acids and comments made against variations in the productivities.**

| Organic acid | BR type | Organism | Productivity ($gl^{-1}h^{-1}$) | Substratum used | Comments | Ref |
|---|---|---|---|---|---|---|
| Lactic acid | FBR | *Streptococcus thermophilus* | 12 | Activated carbon | PBR with PCS can be the best choice | Ho et al., 1997; Tay and Sang, 2002, Cotton et al. 2001; Demirci et al. 1993a, 1993b, 1995 |
| | PBR | *Streptomyces viridosporus T7A + Lactobacillus casei* | 13 ($gl^{-1}$) | Polypropylene + soy hulls-zein (25% w/w) | | |
| | | *Lactobacillus casei* | 102 | PCS | | |
| | ALR | *Rhizopus oryzae* | 104.6 ($gl^{-1}$) | Mineral support + 5 ppm poly(ethylene oxide) | | |
| | ALR | *Rhizopus oryzae* | | Polyurethane foam cubes | | |
| | Rotating fibrous bed | *Rhizopus oryzae* | 60 | Fibrous matrix | | |
| | PBR | *Lactobacillus Casei subsp. rhamnosus* | 9 | Grid-like orientation PCS biofilm reactor | | |
| | | *Lactobacillus casei* | 7.6 | PCS | | |
| Acetic acid | Multistage shallow flow biofilm reactor | *Acetobacter aceti M7* | 4.3 | | MABR, SMABR, SFBR can be explored. | Park and Toda, 1992 |
| | TBR | *Acetic acid bacteria* | 1.67 | Beechwood shavings | | |
| Citric acid | FBR | *Aspergillus niger* | 0.13 | Polyurethane foam (PUF) | PCS can be a better choice to PUF. | Ricciardi et al., 1997; Sanroman et al., 1996; Wang, 2000. |
| | | | 0.11 | Polyurethane foam particles | | |
| | RDC | *Aspergillu niger* | 0.9 | Plastic discs + PUF | | |
| Fumaric acid | RDC | *Rhizopusoryzae* | 4.25 | Polysulfone Plastic discs | SMABR can be explored | Cao et al., 1996 |
| | CSTR | *Rhizopus oryzae* | 0.9 | | | |
| Succinic acid | PBR | *Actinobacillus succinogenes* | 2.08 | PCS | No correlation between biofilm formation and succinic acid production was observed. | Urbance et al. 2003, 2004 |

**Table 6: Different types of antibiotics and MAbs produced employing BR technology and comments made against variations in the productivities.**

| Antibiotic/Antibody | BR type | Organism /Cells | Substratum | Productivity ($gl^{-1}h^{-1}$) | Comments | Ref |
|---|---|---|---|---|---|---|
| Penicillin | FBR (steady state analysis) | | | Theoretical development | Complete-mixed contacting pattern resulted in higher specific productivity. | Park and Wallis, 1984 |
| | Inverse fluidized bed bioreactor (IFBBR) | *Penicillium chrysogenum* | Expanded polystyrene in the form of beads | $5.79 \times 10^{-4}$g (g (biomass)$^{-1}$.h$^{-1}$ | IFBBR favored more production | Ramsay et al., 1991 |
| | CSTR | *Penicillium chrysogenum* | Agar beads | 0.026 | 2.5 times more stable product | Swarooparani et al., 2003 |
| | ALR | *Mutant Penicillium chrysogenum P2* | Celite | | Overcame the problem of the free cell mass | Keshavarz et al., 1990 |
| Penicillin-G | FBR | *Penicillium chrysogenum* | Celite R-630 | 0.11 g Pen-G (K+)/g lactose | | Jones et al., 1986; Deo and Gaucher, 1984 |
| | | | K-carrageenan beads | 1.2 mg/g cells/h | | |
| Cephalosporin C | FBR | *Cephalosporim acremonium* | Celite particles | Production was improved by 1.9 | | Park and Seo, 1998 |
| | ALR | *Cephalosporim acremonium* | Siran particles, Silk sachets, Pellets | Specific Productivity: 180% 150% 125% (as compared to 100% for free cells) | Immobilization modes exhibited enhanced volumetric oxygen transfer coefficient | Srivastava and Onodera, 1998 |
| Nisin | PCSBR | *Lactococcus lactis* | PCS tubes attached on the agitator Shaft. | 4,314 U/mL | | Pongtharangkul and Demirci, 2006c |
| Monoclonal antibody (IgG2b) | Fibrous-bed bioreactor (FBBR) | Hybridoma HD-24 cells | Fibrous matrix | 7 mg/h.l | Productivity was about 23 times higher to flask cultures | Zhu and Yang, 2004 |
| MAb | FBBR | Hybridoma cells | Non-woven polyester fibrous matrix | 6.5 | Highly porous fibrous matrix was advantageous | Yang et al., 2004 |
| Anti-digoxin MAb | PBR | Mouse hybridoma cell | Fibra-Cel | 116-120 microg/day per ml | Continuous-feeding mode was more efficient for large-scale MAb production than a batch culture. | Golmakany et al., 2005 |

**Table 7: Different types of enzymes and their productivity profiles obtained employing BRs..**

| Enzyme | BR/Substratum type used | Organism | Productivity | Comments | Ref |
|---|---|---|---|---|---|
| Cellulase | Woven nylon pads | *Aspergillus terreus* | 453 U/ml | Designs of the biofilm reactors are highly innovative | Hui et al., 2010; Webb et al., 1986; Ahamed and Vermette, 2010; |
| | Spouted-bed reactor | *Trichoderma viride (QM9123)* | 24.7–31.5 U | | |
| | Draft-tube airlift bioreactor | *Trichoderma reesei RUT-C30* | $200\ U\ l^{-1}\ h^{-1}$ | | |
| Tagatose | PBR | *Escherichia coli cells containing Geobacillus stearothermophilus l-arabinose isomerase mutant (Gali 152* | 2.9 g/L.h | | Jung et al., 2005 |
| Lignin peroxidase (LiP) | Hollow fiber reactor and silicone membrane reactor | *Phanerochaete chrysosporium* | | | Venkatdari and Irvine, 1993; Linko, 1992 |
| | Nylon web | *P. chryosporium* | 2430 U/L | | |
| Lignin peroxidase/ manganese peroxidase | PCS tubes attached on the agitator shaft | *P. chryosporium* | 50, 63 U/L | | Khiyami et al., 2006 |
| Manganese peroxidase (MnP | FBR and fixed bed bioreactors with gas pulsation | *P. chryosporium* | | | Moreira et al., 1998 |
| Amylase | Silicone foam | *E.coli* | 15-28 U | | Oriel, 1988 |

**Table 8: Different types of microbial polysaccharides obtained employing BRs.**

| Polysaccharide | BR/Substratum type used | Organism | Productivity | Ref |
|---|---|---|---|---|
| Pullulan | PCS tubes attached on the agitator shaft | *Aureobasidium pullulans* | 32.9–60.7 g/l | Chen et al., 2010 |
| | PCS | *A. pullulans* | 1.33g/l/h | Cheng et al., 2011 |
| | PCS (surface response methodology approach) | *A. pullulans* | 60.7g/l | Cheng et al., 2010 |
| Cellulose | PCS tubes attached on the agitator shaft | *Acetobacter xylinum* | 7.1 g/l | Cheng et al., 2009 |
| Xanthan | Centrifugal packed-bed Reactor (CPBR) | *Zymomonas campestris* | 3 g/l/h | Yang et al., 1996 |
| | FBR (Celite particles) | *Z. campestris* | | Robinson and Wang, 1985 |

formation of the biofilm was more favored compared to other used substrata. It has been claimed that bonechar has the shear force resistance due to its high porosity and roughness and it is hydrophobic in nature (Qureshi et al., 2005; Qureshi and Maddox, 1990). Microbial cells can escape from the detrimental effects of shear forces as shear forces are very low inside pores. By chemical composition, bone char is mainly calcium phosphate. Microbial cells grown in phosphate rich nutrient have a higher tendency to flocculate and adhere due to their increased hydrophobicity, while the cells depleted in phosphate are more hydrophilic and less likely to adhere (Bucks et al., 1998). The phosphate present in the structure might also aid in maintaining a high degree of hydrophobicity on the surfaces of bonechar and *C.acetobutylicum*. The inherent properties of bonechar make it a recognizable adsorbent for common application in biofilm reactor. However, it's not been in common practice for application in PBR reactors. For different products, role of bonechar in the variation of productivity can be evaluated in PBR, provided the reaction parameters are set at optimum conditions for each product. As production of butanol is manipulated at genetic level, efforts can be made to make *C.acetobutylicum* more adaptable to bonechar. Productivity of butanol was enhanced in FBR by more than two fold than in PBR with bonechar. This encouraged the researchers to scale up the FBR technology to pilot plant level for mass production of butanol (Qureshi et al., 2005). Introduction of bonechar into the FBR set up of butanol production after making necessary morphological changes can further enhance the productivity level.

**3. Organic acids**

Organic acids viz. lactic acid (LA), acetic acid (AA), citric acid (CA), fumaric acid (FA) and succinic acid (SA) have been produced using different BRs (Table5). Conventional BRs such FBR, PBR, airlift reactor (ALR), rotating disc biofilm reactor (RDBR), stirred tank reactor (STR) and trickling bed reactor (TBR) have proven to be more productive over their respective suspension cell reactors. Based on the organism, substratum and the type of BRs being employed, productivity of a particular organic acid varied. In general, PCS exhibited better productivity along with technical feasibility for scaling up to pilot plant level. Customization of PCS in its texture or blending imparted better adaptability for application in PBR and FBR for LA production. The aqueous solution of ethanol in contact with air and under the influence of LA bacteria produces LA. The two phase (organic and aqueous) system and need of high oxygen rate transfer makes production of LA ideal for recently developed customized membrane biofilm reactor. Solid support membrane-aerated biofilm reactor (SMABR) and slug flow biofilm reactor (SFBR) are the modern BRs supporting production under aerobic conditions. In the production of CA, FBR and RDC have been explored using polyurethane foam (PUF) as supporting material for biofilm growth. As RDC is preferred for aerobic strains, it resulted in better productivity of CA over FBR. For FA, RDC increased the productivity by many folds over STR. This again encouraged researchers to go for the aerobic process supporting modern BRs, such as SMABR. Productivity of SA was highly influenced when shifted from suspended cell fermentation to PBR with PCS. However, for comparative statement on performance, application of more BRs for SA production is required.

**4. Antibiotics & Monoclonal Antibodies**

Application of different BRs in the production of antibiotics has been explored for a limited number of targeted molecules. Penicillin and its derivative Penicillin-G, new generation antibiotic Cephalosporin-C and the only FDA approved bacteriocin Nisin, have been the prime choice of researchers so far (Table 6). Conventional type BRs such as FBR, ALR and STR are in common practices for the production of these antibiotic molecules. Penicillin has also been produced in the new concept based inverse fluidized bed bioreactor (IFBBR). Production of Nisin was greatly enhanced by the introduction of PCS concept.

The production of single antigen specific monoclonal antibodies (MAbs) from hybridoma cells have also been carried out in BRs. Hybridoma cells are immobilized on different matrices to reach a highly viable and productive cell density. FBBR has been the common choice for MAbs production. Non-woven polyester matrix being highly porous is very efficient in mass transfer, supported the adhered cells for a long time and thus enhanced the productivity of MAbs compared to the entrapment method that employed Fibra-Cel as supporting matrix.

**5. Enzymes**

The inherent enzyme producing property of many microbes has been positively manipulated employing a biofilm reactor set up. However, list of the targeted enzymes is very short (Table 7). Application of the innovative biofilm systems for long term growth of the fungus, *P. chryosporium* resulted in more productivity of the two extracellular ligninolytic enzymes (LiP and MnP). *Trichoderma* species also exhibited good adaptation to different substrata for biofilm development and caused more productivity of cellulase compared to suspension cell cultures. Tagatose and amylase production were also enhanced under the biofilm reactor conditions. More studies are required to encompass all the basic elements supporting the optimum growth of biofilms and finally designing of a biofilm reactor with the scope of scaling up to pilot plant level for the enzyme of interest.

**6. Microbial Polysaccharide**

Application of BRs for the production of microbial polysaccharides has been sparsely experimented. Pullulan, cellulose and xanthan are the three microbial polysaccharides explored using BR technology (Table 8). A detailed description on the progress of pullulan production has been well reviewed (Cheng et al., 2011). In the production of cellulose, application of PCSBR enhanced the productivity. Production of xanthan was attempted in FBR using Celite particles. Centrifugal packed-bed reactor (CPBR) markedly enhanced production of xanthan.

## 7. Lacunae in the present knowledge / understanding of BR technology

### 7.1. Selection of solid support

The whole process of biofilm formation is an outcome of the complicated bio-physicochemical interactions between the microbial surfaces and the solid supports (Fig 2). However, the phenomenon of "biofilm formation" by microorganisms on a solid support follows the same basic principles in the form of some quantitative physical factors (contact angles, free energy of adhesion, total energy of interaction) originating from the close interactions between solid supports and microorganisms. These factors predict the suitability of a solid support for a particular microorganism. Irrespective of any biofilm forming microorganisms, type of BRs, customization of solid support and the product features of a bio-product, these physical factors can never be compromised. High precision in the calculation of these physical factors and their proper analysis would provide a better scientific backdrop support in the selection of a novel solid material for biofilm formation.

Van Oss et al. (1986) suggested that microbial adhesion to a solid support follows extended XDLVO (Derjaguin, Landau, Verwey, Overbeek) theory. This theory is based on the attractive Lifshitz van der Waals (LW), electrostatic double layer (EL) and short-range Lewis acid–base (AB) interactions between microorganisms and substrata. The polar AB component is the result of hydrogen bonding between two surfaces immersed in a polar solvent (e.g., water). XDLVO approach is more precise in quantifying the interaction energy in order to predict the adhesion. According to XDLVO theory, the total free energy of interaction is expressed as:

$$\Delta G^{TOT\,(XDLVO)}\left(mJ/m^2\right) = \Delta G^{LW} + \Delta G^{AB} + \Delta G^{EL} \quad (1)$$

The total interaction energy is evaluated as a function of the minimum equilibrium cut-off distance ($y_0$) between the interacting surfaces. At this distance physical contact is possible between two interacting flat surfaces and generally a value of 0.158 ± 0.009 nm is assigned (Speranza et al., 2004). The distance is also considered as the van der Waals boundaries between the non-covalently interacting molecules which signify the distance between the outer electron shells. Van Oss et al. (1986) mathematically expressed all the three components ($\Delta G^{LW}$, $\Delta G^{AB}$ and $\Delta G^{EL}$) contributing to the calculation of $\Delta G^{TOT\,(XDLVO)}$ per unit area in terms of $y_0$. The equations are presented as follows:

$$\Delta G^{LW}_{\gamma_0} = -2\left(\sqrt{\gamma_s^{LW}} - \sqrt{\gamma_l^{LW}}\right)\left(\sqrt{\gamma_m^{LW}} - \sqrt{\gamma_l^{LW}}\right) \quad (2)$$

$$\Delta G^{AB}_{\gamma_0} = 2\left[\left(\sqrt{\gamma_m^{+}} - \sqrt{\gamma_s^{+}}\right)\left(\sqrt{\gamma_m^{-}} - \sqrt{\gamma_s^{-}}\right) - \left(\sqrt{\gamma_m^{+}} - \sqrt{\gamma_l^{-}}\right)\left(\sqrt{\gamma_m^{-}} - \sqrt{\gamma_s^{-}}\right) - \left(\sqrt{\gamma_s^{+}} - \sqrt{\gamma_l^{+}}\right)\left(\sqrt{\gamma_s^{-}} - \sqrt{\gamma_l^{-}}\right)\right] \quad (3)$$

$$\Delta G^{EL}_{\gamma_0} = \frac{\varepsilon_0 \varepsilon_r \kappa}{2}\left(\zeta_s^2 + \zeta_m^2\right) \times \left(1 - \coth(\kappa\gamma_0) + \frac{2\zeta_s\zeta_m}{\zeta_s^2 + \zeta_m^2}\operatorname{csch}(\kappa y_0)\right) \quad (4)$$

where,

(I) $\gamma_s^{LW}$, $\gamma_l^{LW}$ and $\gamma_m^{LW}$ represents the surface tension components of a solid surface (s), three probe liquid (l) and microorganism (m) respectively,

(ii) $\gamma^{+}$ and $\gamma^{-}$ represent the electron-accepting and electron-donating parameters of each surface tension component ($\gamma_s^{LW}$, $\gamma_l^{LW}$ and $\gamma_m^{LW}$) and

(iii) $\varepsilon_0$ (=8.854×10$^{-12}$ CV$^{-1}$m$^{-1}$) and $\varepsilon_r$ (=79) are dielectric permittivities of a vacuum and water, respectively, κ (=3.28×10$^{9}$ I$^{1}/^{2}$ m$^{-1}$, where I is the ionic strength of the electrolyte in terms of molarity) the inverse Debye screening length, and ζs and ζm the surface potentials of the solid surface and microorganism respectively.

In the case of flat-spherical surfaces, interacting at minimum equilibrium cut-off distance (h), the total interaction energy ($U^{TOT}$) profile is calculated as per Derjaguin's approximation and expressed as:

$$U_h^{TOT} = U_h^{LW} + U_h^{AB} + U_h^{EL} \quad (5)$$

where,

$U_h^{LW}$ = LW component of interaction energy

$$= 2\pi\Delta G^{LW}_{\gamma_0}\frac{\gamma_0^2 a_p}{h} \quad (6)$$

$U_h^{AB}$ = AB component of interaction energy

$$= 2\pi a_p \lambda \Delta G^{AB}_{\gamma_0} e^{[\gamma_o - h/\lambda]} \quad (7)$$

$U_h^{EL}$ = EL component of interaction energy

$$= \pi\varepsilon_r\varepsilon_0 a_p\left[2\zeta_s\zeta_m \ln\left(\frac{1+e^{-\kappa h}}{1-e^{-\kappa h}}\right) + \left(\zeta_s^2 + \zeta_m^2\right)\ln\left(1-e^{-2\kappa h}\right)\right] \quad (8)$$

$a_p$ represents radius of the cell.

In general, calculation of total surface tension of a pure substance is expressed as the sum of a LW and AB components as suggested by van Oss *et al* (1986). The equation is given as:

$$\gamma^{TOT} = \gamma^{LW} + \gamma^{AB} \quad (9)$$

For each component, the expression is given as,

$$\gamma^{AB} \text{ or } \gamma^{LW} = 2\sqrt{\gamma^{+}\gamma^{-}} \quad (10)$$

Again, for a solid surface or a microorganism under study, $\gamma^{AB}$ or $\gamma^{LW}$ can be calculated by putting the contact angle data of a three probe liquid (water, diiodomethane and ethylene glycol) in the extended Young equation which is expressed as:

$$(1 + \cos\theta)\gamma_l = 2\left(\sqrt{\gamma^{LW}\gamma_l^{LW}} + \sqrt{\gamma^{+}\gamma_l^{-}} + \sqrt{\gamma^{-}\gamma_l^{+}}\right) \quad (11)$$

Where, θ = Measured Contact angle.

For many microorganisms used in BR based production, predictive utility of XDLVO theory was found to be precise than the DLVO theory. Experimentation done on the adhesion behavior of bacteria and *S.cerevisiae* onto different treated surfaces confirmed the involvement of factors of XDLVO origin (Bayoudha et al., 2009; Kang and Choi, 2005). Although such studies are confined to specific microbial strains, the concept is also applicable to the unexplored ones.

PCS has been shown to be an excellent solid support material for many BR based bio-products. Compatibility of the used microbial strains to PCS resulted in manifold increase of productivity. Both quantitative (measurement of contact angle) and qualitative (scanning electron microscope based topological studies) data supporting the adhesion and biofilm formation respectively, have been included in those studies (Ho et al., 1997). However, mere consideration of surface hydrophobicity/hydrophilicity on the basis of contact angle measurement can only support DLVO theory. Surface manipulations (such as, blending, activation etc.) for better adhesion of microorganisms must be supported as all the criterions come under the XDLVO approach. Constant solution chemistry (culture media and other ingredients) will be a pre-requirement in obtaining precise data for XDLVO consideration. XDLVO approach combines the thermodynamic approach and DLVO theory to explain the experimental results of microbial adhesions (Katsikogianni and Missirlis, 2004). To overcome the limitation of broad application of a solid support, XDLVO can be exploited as a promising model for the prediction of physic-chemical interactions between solid support surface and microbes. In addition, chemical composition of a solid support is a deciding factor for the adhesions of microorganisms. Polymers of different molecular weights, lengths and molecular structures (isomers) might respond differently to a microorganism. If it is assumed that, agricultural waste products (AWP) and the plastic support present in PCS chemically inert to each other, the accessibility of AWP to a microorganism can still be sterically hindered by the orientation of the monomer chains constituting the plastic support. This concept is applicable to any novel solid support to be developed considering PCS as a model substratum. More investigation on the molecular interactions between a nutrient cum solid support material and microorganisms can reveal the governing factors for a better adaptability of microorganisms to be used for different bioproducts in BRs.

As opposed to the current tendency of random search, applications of biomaterials research findings and nanotechnology concepts in the direction of prospective design or selection of a novel solid support can give predictive outcome. Cellulose acetate (CLA), the photodegradable but not biodegradable and renewable biomaterial can be a good option as solid support and biofilm carrier (Hon, 1977). CLA has already found wider applications in biomaterials and tis sue engineering (BMTE) field as it can mimic the topology of an extracellular matrix (Han and Gouma, 2006). Evaluation of CLA (sourced from cigarette waste filter rods) as a biofilm carrier in an integrated fixed film activated sludge (IFAS) process was very encouraging (Sabzali et al., 2011). Compared to the activated sludge (AS), the CLA integrated IFAS performed better in terms of the removal efficiencies of COD, ammonia and phosphorus. Being a renewable (mainly sourced from wood pulp) and cheap material, CLA has the scope of more applications in BRs technology as solid support for biofilm formation and biofilm carrier. Application of nanotechnology in designing more efficient solid support for biofilm formation can also be vital. Electrospining (a fabrication method used to form complex, porous, 3D structures with specific design in terms of geometry, morphology or topography in a single-step process) of solid support in its soluble form into nanosheets of desired porosity, thickness and surface area can give a better form of solid support for microbial adherence. Application of nanofibers (polyethylene + polyurethane) as a carrier of the biofilm of bacterial strain *Rhodococcus erythropolis* for wastewater treatment in a MBBR, found to be better than the commercially available AnoxKaldnes (type K3) carriers (Kriklavova and Lederer, 2010). Growth of the bacterial biofilm within the nanofibers not only facilitated more protection for the bacteria against the toxic effects of the surrounding environment of wastewater, but was also able to provide substrate and oxygen to the microorganisms in sufficient amount. Thus, it is obvious that application of biomaterials and nanotechnology concepts in the customization of solid supports can have serious impacts. However, in-depth studies are required to make these novel concepts fruitful and also an integral part of BRs technology.

**8.2. Water structure, solid surface and microbial response**

Water structure (three-dimensional hydrogen-bonded network) associated with 'hydrophobic' and 'hydrophilic' solid surfaces are different as given in Fig 3. This property of water is attributed to the strong nature of self- association of its molecules. In a polar solvent system, such as water, molecular association is dependent on the acid-base interactions taking place between molecules in solution or between solution-phase molecules and a solid surface. Lewis acid and base is required for this polar environment which has a direct effect on the polar interactions among the molecules involved, thus influencing the interfacial phenomena. Another important aspect of water-solid surface interactions is the analytical measurement of hydrophobicity. Techniques that directly probe water structure rather than those that simply respond to water structure, such as contact angle and wettability, should be more preferred. Measurement of surface forces with surface force apparatus (SFA) and ancillary techniques are one such approach to quantifying hydrophobicity. Apart from the water structure and hydrophobicity that influence the water-solid support interactions, another major factor which contributes to the role of water in biological response (microbial surfaces) to materials (solid support) is the measurement of 'water wettability' in terms of 'adhesion tension' (denoted as $\tau^0$), rather than surface energy ($\gamma_s$) or interfacial tension ($\gamma_0$) components that are found to be distantly related to water wettability (Vogler, 1998).

Water adhesion tension ($\tau^0$) can be derived from the known value of water interfacial tension ($\gamma^o$) and measurement of contact angle ($\theta$). The expression is given as:

Where,

$$\tau^0 = \gamma^o \cos\theta \tag{12}$$

$\tau^0$ = Water Adhesion Tension (dyne/cm)
$\gamma^o$ = Water Interfacial Tension (= 72.8 dyne/cm for pure water)
$\theta$ = Measured Contact Angle

**8.3. Berg Limit**
The concept of 'Berg Limit' can precisely be applied in the measurement of surface forces (attractive or hydrophobic/repulsive or hydration) acting on a solid surface immersed in water. Berg et al suggested for a 'threshold' value of contact angle ($\theta = 65^0$) for separating the zone of hydrophobicity and hydrophilicity of solid surfaces immersed in water (Berg et al., 1994). This contact angle value can be exploited to determine the 'threshold' value of $\tau^0$ for predicting the water wettability properties of different solid surfaces.

From equation (12),
At 'Berg limit' $\theta = 65^0$

$\tau^0 = 72.8 \text{ X } \cos 65^0$
$= 72.8 \text{ X } 0.4226$
$= 30.76$ dyne/cm

Thus, according to 'Berg Limit' concept

(1) For hydrophobic surfaces, $t^0 < 30$ dyn/cm, $\theta < 65^0$ and

(2) For hydrophilic sufaces, $t^0 > 30$ dyn/cm, $\theta > 65^0$.

**8.4. Primary & secondary minima of adhesion**
Adhesion of microorganisms to different substrata under high flow velocity can either be reversible (partial or complete detachment) or irreversible (zero or negligible detachment). Due to the heterogeneity in the surface properties of different microorganisms and substrata, the adhesion energy profiles ($U_h^{TOT}$) of interactions at different contact points differ. The high adhesion energy profile causing the strong attraction at some contact points are called as "Primary Energy Minima", and those contact points where the adhesion energy profile is relatively weak are known as "Secondary Energy Minima" (Kang and Choi, 2005). Reversibility or irreversibility of microbial – substrata interactions is a net outcome of the relative abundances of primary or secondary energy minima, which in turn is highly susceptible to surface properties of microorganisms or substrata itself. Experiment on the detachment of microbial cells from a substratum surface is vital as the product features will be highly affected by too much reversibility nature of the adhesion energy profile. Thus, while adopting a novel solid support material for BR, test of reversibility seems to be mandatory for a proper scientific evaluation of applicability of a substratum at commercial scale. Favouring of hydrophobic or hydrophilic surfaces for biofilm development by different microorganisms and sustainability of irreversible condition (no detachment) in a long time running set up of a BR are the mere consequences of adhesion energy minima profiles of the interactions. Reports on the successful application of a novel substratum for BR based productions are not inclusive of adhesion energy minima concept. Most of the findings are based on the measurement of contact angles and specifically designed for a particular strain of microorganism. This area of BR technology needs further exploration to make the application of a substratum even broader.

**8.5. Entropy of Mixing**
Mixing of two materials change the thermodynamic property called "entropy of mixing" even though they are chemically non-reacting. The entropy of mixing provides information about differences of intermolecular forces or specific molecular effects in the materials. Though not considered as a common factor in BR technology, analysis of entropy of mixing can be relevant to designing of composite solid supports like PCS. This thermodynamic property can have a predictive value in fixing the ratios of blending materials (organic or inorganic) in the development of a novel and better performing composite substratum to be applied in BRs. In a recently published report, it has been shown that even the method (ethylene oxide or gas plasma) adopted for surface sterilization of a substratum can have huge impact on the adherence level of bacteria (Kinnari et al., 2010). Analysis of entropy of mixing for different ratios of ingredients can help in knowing (a) any chemical interactions in-between the ingredients and (b) thermodynamic impact of each ingredient in the overall performance of a composite substratum. In the near future also, researcher might develop interest in designing a novel composite solid support, more efficient than PCS at the expense of even more cheaper waste materials from agricultural or other sources. In such an approach, it might be possible to select the ingredients in a more easy but accurate way by employing the concept of entropy of mixing.

**Concluding remarks**
The effort for utilizing the natural phenomenon of "biofilm formation" by microbes in the benefit of human has been well manifested in the form of BR technology. The systematic approach made towards the development of a novel BRs resulted in multiple impacts on the production level of different bioproducts. The key factors controlling the performance of biofilm can now be regulated at molecular level. However, when explored from the lab to commercial scale translation level, the present scenario of BR technology is not satisfactory except one or two bioproducts. The contemporary efforts made for enhanced productivity, utilization of waste materials as sources of carbon and energy, designing of composite solid supports and customization of BRs, in a collective manner has not been able to put the BR technology in an easily scalable platform by adopting common features. The divergences arises due to the application of bioproduct or microorganism or BR engineering aspect specific elements (solid support, culture condition, microbial strains and BR hydraulics) and they have restricted the scope from further scaling. Thus, a unified concept on the development of a substratum for a particular

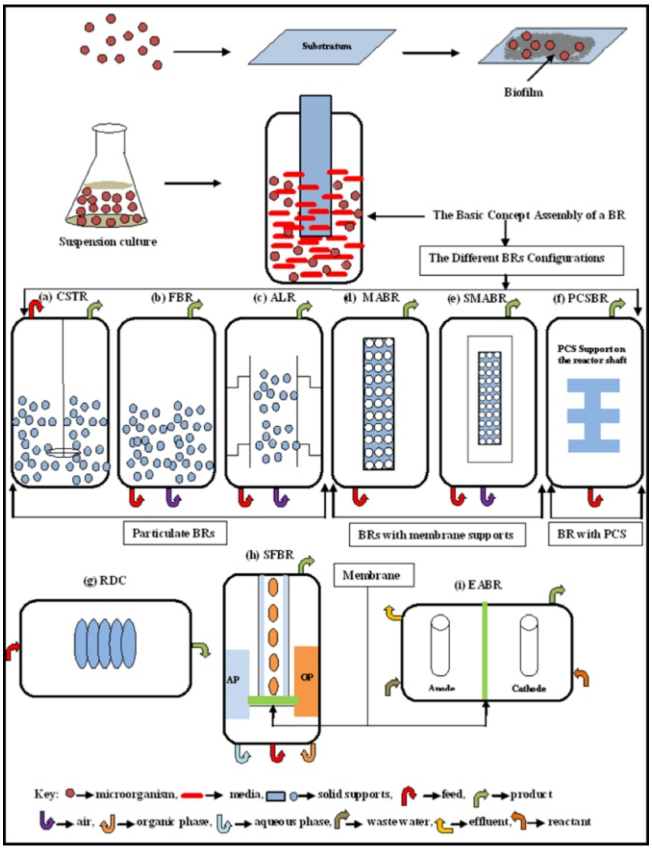


**Fig 1: The concept of BR technology and its development.**


**Fig 2: Schematic outline of different steps of biofilm formation mechanism.**

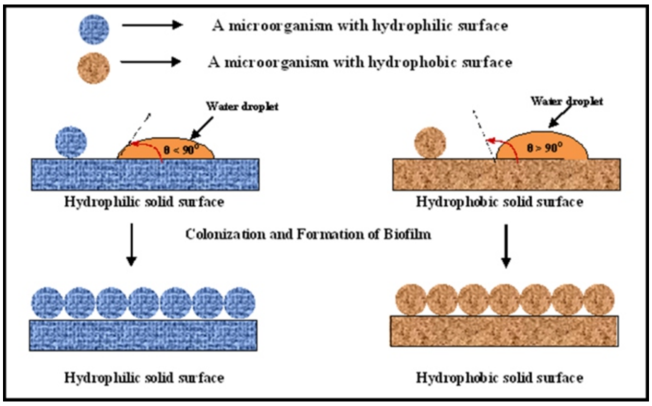


**Fig 3: Summary of the surface properties of microorganism and water molecule involved during formation of a biofilm on a substratum.**

bioproduct (single or multiple microorganisms specific) will be a preferred approach. The material chosen as a substratum alone or component for composite support designing must be subjected to the analysis for some quantified parameters (XDLVO analysis for adhesion energy, energy minima, Berg limit and entropy of mixing) before approval for common application in BR technology. In a positive sense, PCS can be foreseen as a substratum for broad applications, but more technical rectifications are required before approving it as a default choice in BR technology. Extensive molecular level

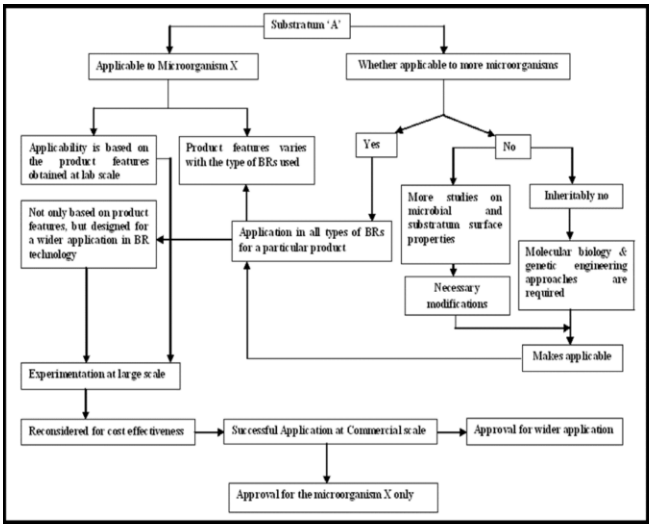


**Fig 4: Schematic outline of the overall concept of the present review.**

research in the direction of developing chimeras capable of adopting to the substratum of default use can make BR technology more converging in the aspect of prevailing great diversification due to the orthodox 'bioproduct-microorganism-substratum-BR type' working principles. The underexplored research areas of the substratum concerned, highlighted in this review article, in a straight forward way have practical impacts on the overall performance of BRs. Along with the customization of engineering aspects of BRs; proper exploration of the substratum associated issues mentioned in the present context can be fruitful in making BR technology more productive and uniform.

## Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Abbreviations

BR, biofilm reactor; RBC, rotating biological contactors; COD, chemical oxygen demand; BOD, biological oxygen demand; BFB, biofilm fluidized bed; TBR, trickling bed reactor; PBR, packed bed reactor; FBR, fluidized bed reactor; ALR, airlift reactor, MBR, membrane bed reactor; RDC, rotating disc contactor; MABR, membrane aerated biofilm reactor; SFBR, slug flow biofilm reactor; AP, aqueous phase; OP, organic phase; SMABR, solid support membrane-aerated biofilm reactor; PCSBR, plastic composite support biofilm reactor; RDBR, rotating disc biofilm reactor; EABR, electro-active biofilm reactor; CSTR, continuous stirred tank reactor; PCS, plastic composite support; PUF, polyurethane foam; IFBBR, inverse fluidized bed bioreactor; CPBR centrifugal packed-bed reactor; OA, organic acids; LA, lactic acid; AA, acetic acid; CA, citric acid; FA, fumaric acid; SA, succinic acid; MAbs, monoclonal antibodies; FDA, food and drug administration; DNA, deoxyribonucleic acid; Lip, lignin peroxidase; MnP, manganese peroxidase; XDLVO, Derjaguin, Landau, Verwey, Overbeek; LW, Lifshitz van der Waals; EL, electrostatic double layer; ZB, Lewis acid–base;

SFA, surface force apparatus; CLA, cellulose acetate; RSM, response surface methodology.

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# PROFESSIONAL COURSES MUST ADD TO DISPOSE OF THEIR WASTE PROPERLY

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**Abstract**
Developed and developing nation has three alarming challenges, which should be taken care properly before it is too late, these are -

- Bio-medical Waste-The professional must know how to handle their waste as bio-medical waste . If world-wide been properly managed than the world might have not faced the situation like Covid-19 (SARS-COV-1), Bird Flu (HSNl), Swine Flu (HlNl) and so on. The professional must know to keep them safe before other safety by managing their waste properly.
- Modern Warfare Waste - Modern warfare consist of Chemical Weapons, Biological weapons, as well as nuclear weapons, recent war of Russia-Ukraine, Israel -Philistine, Taliban Incidence of Afghanistan, ISIS- Syria, Iran-Iraq war,conflict and so on. These wars are not face to face War, more over Missile, Rocket, Bombs are used, which destroy the fertile land, greenery a nd the beautiful air index. The solders are responsible for doing the war but the citizens face the consequences, if the live bomb or bomb shell not properly taken care of. The professionals must know which kind of bomb or rocket is there and should be removed from the site for proper disposure, Police must take care of these warfare by which the air pollution must be taken care immediately.
- Space Garbage - The world is moving fast towards the digital world or we can say that now internet is a part of present life, means the satellite services . These Space satellite or Space research station has certain life span the time, and after the life time they become threat to the earth as in 1979, USA- Skylab accidently fall on the earth, Tomorrow second incidence can also happen. These Space research organisations must educate their professional to handle such type of space garbage. By educating the professional with Space Garbage management, we can not only give beautiful path for their work but also play an important role for Green and Healthy earth to live.

**Keywords**
Skylab, NASA, D.U. , NATO. ISRO. UNOOSA.

## INTRODUCTION

Waste or garbage is the substance discarded after primary use or is worthless, defective and are of no use. We can understand that the sources of Waste can be classified into 1. Industrial 2. Commercial 3. Domestic. 4.Agriculture . It can be disposed by1. Landfill 2. Incineration 3. Waste consumption 4. Composting 5. Verme-composting.

Now the question is Do-we manage our garbage well? while depending on others will never get the hundred percent result. Only self-approach can assure it. It is better to do self than depending on others. In our country India itself, there are nine Universities providing - Waste management courses. The bachelor and master degree on 1. Waste and Resource management 2. Population management and control 3. Environmental pollution 4. Environmental management.

These courses depicts that the Waste management or garbage management is a big challenge of today's society for healthy and peaceful life and it should not be kept on the other solder. Bio-medical, Modern warfare and Space garbage does not

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know the boundaries meaning there by these waste management are not the part of the state or Government (federal government). These wastes are threat to the Mankind across the world, So the all over the countries must come forward to solve the problem which are the boundaries less problem (across the world).

Is Garbage or Waste management the only government responsibility? -

The garbage or the waste created by self, I am first responsible to take care of it, but majority of time we put the wastes on the concern society or government to take care of it. If we make too late to manage the garbage the environment become more poisonous more toxic, Timely disposal of waste is essential for the society for healthy living, if not done in time can be a cause of Fungal, Bacterial or Viral Infections thus immediately should be taken care.

Now the private organisations are coming up to provide waste management properly beside the municipal corporation like so on. In other wards government services to the garbage management is not sufficient . Since we depend on others, there are two questions in our mind for waste management service, firstly we have to pay for it and secondly the accuracy is not sufficient as perfect.

Let us now take responsibility to manage our own wastes, we have noticed that when we depend on others the satisfactory level and amount will be at high risk, so why should not we move forward to manage our wastes by self-management, the satisfaction level and savings will be in our favour.

Let us now Educate our people at the first stage of waste handle, we have already seen that there are nine university providing education of waste management or pollution management in India, that means there is scope that big organisation should come up with their own planning with the help of education institutes to manage their garbage.

Educate our professionals to make the world Clean & Green: -

We must educate our professional, many institutes are coming up but the problem are with different types of waste in particular the Hazardous or dangerous wastes . We will discuss only the above mentioned three categories of dangerous waste.

1. Bio-medical waste: - Newspaper The Hindu in Jan 2021 said with reference to Government Medical College, Kochi with Government state land monitoring committee (SLMC) to study waste disposal "Bio-medical waste mixed with food waste found dumped inputs, the state pollution control board (PCB) has submitted the report that state still a lot of steps to be taken for proper management of bio-medical Waste".

   Wuhan Institute of Virology, China if properly handle or disposal the bio-medical waste the covid-19, pandemic may not have spread, we can say since these waste leak in virus or not properly disposed leads to the big problem of SARS-COV-1.The Inspection of the Wuhan Virology Institute, which conducts research on the world's most dangerous disease - the origin of the Covid-19 pandemic. The sensitive mission, which China had delayed throughout the first year of the pandemic, has a remit to explore how the virus jumped from animal to human. WHO must take it as serious matter,why China has not co-operated on this issue.

Swine Flu or Swine Influenza (HlNl) virus started in pigs first recognised in 1919 and still a seasonal flu virus.

Bird Flu (H5Nl) avian influenza virus primary infects birds but can also infect human. In 1996 first identified in domestic water fowl in Southern China. The matter of concern is that Bird flu and SARS-COV-1 virus spread from China that means Bio- medical wastes is not properly managed.

World Health Organisation (WHO) states that 85% of bio-medical wastes are non-hazardous and 15% are hazardous materials that may be infectious, toxic, or radio-active. Every year an estimated more than 16 billion injection are used with sharp needle - an alarming for AIDS or Hepatitis-B like situation .

The 20th Century worst pandemic 'Spanish Flu' erupted in March 1918 in Camp Funston (Kansas, US), much like Covid-19. It spread globally at an astonishing wave took about Three crores (30 million) lives in four months. The half of death occurred in India means 1.5 crores the cause of death is the Virus like Covid -19 Virus.

September 1994, plague struck Surat, a city in the state of Gujarat in western India the Pneumonic outbreak.

Cholera, it has been said was the Chronic epidemic disease of nineteenth century. The epidemic of the 1830, 1840 and 1860 have been identified as causing popular unrest accentuating social conflict and providing a catalyst for Municipal reforms and the development of public health

International Committee of Red Cross (ICRC) has issued a book for the medical fraternity Medical Waste Management. There is a guide line provided by the red cross society for proper disposal of bio-medical waste . Here we have seen that International Red Cross Society is serious about this important issue but because the present facility is bio-medical waste management is not sufficient .

Now our request is each and every medical faculty must know their waste properly and understand the proper disposal. When each and every Institute become alert about their proper disposal of the waste than Bid flu or SARS Cov-1, Swine Flu, will not happen.

United Nations and WHO must assure that each and every country must follow the mankind related rules. Must call all the nations to come up that such incidence should not happen again. For this important issue International Red Cross Society should be the part of it.

2. Modern Warfare: - Now a days we witness the war between Russia- Ukraine, on other word NATO verses Russia, before the long battle of Iran-Iraq happened, Pakistan Invasion to Kargil, Syria - ISIS conflict, Israel - Philistine conflict has been witnessed in the 2151 Century. Over all we have noted that War is an unwanted incidence, which one has to face, where all country become part of it.

   When all developed or developing nations become part of it resulting all modern Rocket, Missiles, laser guided bomb, DU bomb or Biological Bombs. These modern Ammunitions are more dangerous than before.

   My request is that the professional courses of armed forces must include and educate their forces, how to safe guard from the dangerous waste available at the battle field or we can say how to manage the warfare waste for the safety and healthy life of the citizen. In otherwords when the arms forces are involved in battle the local police should be educated to proper removal and disposal of the missile, rocket, shell etc.

   Recently we have noted that only U.S. Armed forces has taken initiative to solve the garbage problem of Iran-Iraq war. The question is why only U.S.A, should do such a dangerous work after the war, why not each and every country develop their own forces to overcome with such an important Job. There another author said "Sitting at land fills of hazardous waste in Iraq from geological perspective" while reporting from Iraq.
   Timely removal of war waste is necessary to avoid as In Iraq, every living was dying, Iraq has never had a radio-active material disposal facility and the lack of a disposal facility because

   D.U weapons was being used during war.

   There is no proper strategy national or international program for cleaning D.U or advance weapons garbage. As Iraq war winds down U.S. Military clean up hazardous waste hundred barrel of Oil Filter, powerful chemical and hydrochloric acid or lithium batteries etc as per "Standard Environment Production Agency (EPA)" guidelines .

3. Space Garbage: - We all know that the space is the region beyond earth atmosphere at the Kamran line, currently defined as an attitude of 100 kilometre. Current Waste disposal method as the International Space Station relay on Astronauts manually processing trash by placing it in to bags, then loading it into a designated vehicle in short term storage, which depends on the craft return the trash to earth or burns up in the atmosphere. NASA seeks new ways to handle trash for deep space mission- regular cargo resupply mission delivers approximately 12 Metric ton of each year.

   The US Space Laboratory SKYLAB -1, launched in 1973 which tremble back to earth in 1979, scattering debris across the Southern Indian Ocean and sparsely populated western Australia. The 77.5 tons Skylab could break in 500 pieces.

   The Waste created by Rocket or satellite or debris created by rocket launching, is free flowing in the space not only today, but also of tomorrow, it will create a threat to the other satellite too. Now the time has come to plan how to handle such garbage of space for free service of satellites.

   In 1979 Skylab of US tumbles back to earth is not a first case as a big threat to the world peace and harmony. The way more and more satellite are being launched, such type of incidence may increase? therefore more threat to the earth for harmony.

   According to the United Nation Office of Outer Space Affaire (UNOOSA), there are 11,330 individual satellite orbiting the earth at the end of June 2023 . This represents almost 40 % present increase since January 2022.

   It is to be noted that among 11,330 only 7,702 active satellite in various earth orbit, then what about non-functional satellite the Waste?

   When we consider India first ISRO launched Aryabhata in 1975. After nine-year gape in 3rd April 1984 Soyuz T-11, Indian cosmonaut Rakesh Sharma embarked with two Soviet Cosmonauts, however in the recent 10 ten years India has made the records of launching the Satellites.
   Now the time has come to understand the Waste management of Space. The professional must plan to stop or minimise the garbage of space. No other than the expert can plan or educate themselves to make the earth safe and green.

**CONCLUSION**

We understand the government trying to solve the problem of waste management but the Success rate is not up to the mark, example we have seen in China of Covid-19 or Bird flu. The medical Waste is still a big challenge which includes AIDS or Hepatitis-B like viral problem. To solve it from the bottom-line health Professional must be educated to disposetheir waste properly and in time. The guidelines of Red Cross Society can be shared for proper safety of the society world over. Big hospital or Institute must have their own Waste Management Unit, like recently all big Institute had their own Oxygen generating plant, not dependent on others .

WHO should come up with all the developing and developed nations to make a proper guideline for the Bio-medical Wastes and must inspect the research Centre of Virus, Bacteria or other Research Institute.

Modern Warfare are more dangerous because of its components like nuclear bomb, biological bomb or chemical bomb. Every country soldier must be given the knowledge, how to safe guard the society if attacked with nuclear weapons by the enemy, we must not forget the incidence of Japan 1942, Hiroshima and Nagasaki disaster. The forces must not only diffuse the bomb but also permanent removal from there. As a sum-up armed forces around the world must put in the syllabus how to overcome with debris of nuclear weapons chemical weapons- biological weapons. To depend on one Country USA is not sufficient to the world.

China, India, United States, North Korea, Russia, have big armed forces along with France, Israel, United Kingdom and Russia have the most advance weapons. All these developed countries must come to gather under the umbrella of United Nations to solve the consequences after the Warfare wastes.

At Space, it is good that Astronauts manage their personal waste by putting it in a bag and taking it back to earth for disposal but the waste created by the Rocket is still in the space which is not good for the world over therefore the time has come to come forward and educate the researchers of space centre to work on it and try to solve the garbage of space. The Skylab created Panic world over, should not happen any more so take the step to collect the garbage and proper dispose by which Earth can remain the safe and healthy for the people. As a Sum-up, Space research Centre must add in their syllabus the present problem of space waste and do work to stop or remove or minimise it.

The United States, Japan, India, China, Israel, France, United Kingdom, Russia, South Korea have the capacity to send objects into orbit with their own space vehicle. Therefore, they must come together to look into the waste of Space in particular the Satellite non function and so on, must come forward to look into the space problem.

Life threatening tough waste and its management is not only a state policy matter, more over it is a job of Federal government or Central government. These mentioned field as Medical (Health), Modern warfare (Defence - Home) and Space (Space research) are more with Federal Government . Thus,the Central government must come forward to develop their professional to extend by which they can act fast and solve waste-garbage in time for better quality of and healthy life. Resulting better quality of Air index to survive and good soil or greenery or good crops to live on earth.

As Conclusion big institutes or professional must understand that their wastes are their responsibility and they must take care of proper disposal by educating their peoples, when every professional take care of their waste certainly we will have good position by improving the global warming or environmental pollution.

**Key word**

D.U = Depicted Uranium.
NASA = National aeronautics and Space Administration, USA. ISRO = Indian Space Research Organisation.
Skylab = US Space laboratory,
NATO = North Atlantic Treaty Organisation.
UNOOSA = United Nation Office for Outer Space AFFAIRS.

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**SAVE THE ENVIRONMENT (STE)** was founded and registered on 19th November 1990. In 1992 with the collaboration of WWF (India), the organization started working to combat arsenic poisoning problem of water in the arsenic prone areas of West Bengal. Since then STE has been involved in various projects related to combat arsenic problem in India.

**Our Vision**
To protect present and future generations from various environmental hazards.

**Our Mission**
To create awareness and motivation among rural communities & provide cost effective, energy efficient & environment friendly technologies.

**Our Activities**
Conducting interactive sessions, workshops/ seminars, awareness programs, field operations through projects, science fairs, posters & quiz competitions.

**Please join us and become part of our family**
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