

A Review on Chemistry of Water Pollution; Chemicals Responsible for Diseases in Living Beings & Their Control

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ABSTRACT

Earth has plenty of water rather 71% surface of earth is occupied by none other than water itself. However, when we use the slogan “Save Water” then it’s not related to saving this 71% of water rather it’s related to saving of fresh underground water, which is useful for drinking purpose. No doubt we have a lot of water on earth but major portion of this is polluted, which is not useful for living beings. Surface water is needed to be protected from pollution only and we have to save the underground water for different purposes of living beings. We emphasize on saving of fresh, drinkable underground water because withdrawal rate of an aquifer is very much larger than the natural recharge rate i.e. the rate with which we withdraw ground water from the aquifer is very large and the rate with which running water seep through the pores of earth into aquifers is very slow. India being largest user of groundwater in the world, on an average it uses 230 cubic kilometer of ground water, it is a more than 1/4th of total global use. More than 60% in irrigation and more than 85% of drinking water supply depends on the ground water in India. So, it’s very much needed that we should save ground water otherwise it will be too late to even get the drinking water from earth. Moreover, surface water is also polluted, if we will keep on spreading the pollution like this then many diseases will arise, which will affect plants, animals and human beings i.e. the whole ecological niche. The only remedy is; save ground water and make the surface-water pollution free.

Key Words: *Aquifer, Ecological Niche, Recharge Rate, Water Pollution.*

I. INTRODUCTION

Chemical composition of water is H_2O with the chemical name '*Hydrogen Oxide*' and it is utmost essential chemical for the living beings i.e. humans, animals & plants. The presence of water on a planet is the source of life over there. About 71% surface of earth is covered with hydrogen oxide i.e. water, however, only 3% is the fresh water while remaining 97% is sea water; which is not fit for drinking or irrigation etc. Out of this 3% of fresh water 2.1% is in the frozen form of Glaciers which is locked water, only 0.9% is available as ground water, water in lakes, rivers & streams etc. The main concerned thing i.e. ground water is just 0.72% of the total water. We cannot melt the water of glaciers or ice caps to meet the requirements or the desalination of sea water to produce fresh water will be too costly, hence we are left with the only option and that is 'Save Water'. Undoubtedly there is plenty of water on earth, majority portion of the earth is occupied with water only but still fresh water for drinking and other household tasks is very less. Water in rivers, lakes, streams, natural or artificial reservoirs, wetlands etc is called surface water whereas the water that percolates through the pores of earth into the ground is called ground water. The layer of soil or rocks that can take in and hold the percolated water is called an aquifer. For the irrigation, drinking purpose and other daily requirements we extract water from these aquifers with the help of pumps and all. Now, if the rate of withdrawal or extraction of water from the aquifers is more than the natural recharge rate then it becomes alarming and it lower down the water table of the underground water. If the surface water is free from pollution then it can be used for various household requirements and we will need withdrawal of ground water to the lesser extent. In this way keeping the ground water pollution free is directly proportional to saving the ground water. Anything which makes water unfit for use is called water pollutant and that this phenomenon is called water pollution. Chemicals which create water pollution are Nitrates (NO_3^-), nitrites (NO_2^-), heavy metals like, Mercury (Hg), Arsenic (As), Lead (Pb), Cadmium (Cd), Selenium (Se) etc, Ammonia (NH_3), Sulphates (SO_4^{2-}) and Sulphides (S^{2-}), Phosphorus (P) and Phosphates (PO_4^{3-}), Hydrocarbons (H_xC_y) and Oil Spills etc ^[1-3].

II. REVIEW OF RELATED LITERATURE

1. Water Pollution; Causes, Effects and Remedies by Kaberi Murmu.

After an intense review of this paper the main observations and noteworthy points were as follows:

1. Water is the greatest source for the sustainability of life.
2. It is a very significant chemical in both domestic as well as industry purposes.
3. Closer analysis showed that our water bodies have become just like pool of poison.
4. Methods to control discharge of pollutants into water bodies; directly or indirectly.
5. Control of abuse of water bodies.

2. Monitoring of Ground Water Level by Ministry of Jal Shakti Posted on 05 Aug 2021 by PIB Delhi

Central Ground Water Board has been monitoring the ground water levels in the entire Country, periodically on a regional scale, with the help of a network of monitoring wells. Studies on water level data reveals that about 68.0% of the wells analyzed have depth to water level up to 5.0 m below the ground level. The deeper ground water level has also been found in isolated pockets of some of the States & UTs. State wise distribution and depth of water level of wells for November 2020 is given. As Conservation of water is a State subject, so, initiatives on water management like water harvesting and saving of water in the Country is primary responsibility of a state. However, the significant measures taken by the Central Government of India for water-conservation, management of ground-water and effective implementation of rain water harvesting in the entire country are available at the following URL:http://jalshakti-dowr.gov.in/sites/default/files/Steps_to_control_water_depletion_Feb2021.pdf.

3. Ground Water Facts

This paper is intensively based on different facts regarding ground water, its depletion and conservation. The main facts obtained from this study are summarized below:

1. Ground water is that water which occupies cracks and other openings of rocks and soil.
2. Every drop of rain penetrated into earth and fills the groundwater reservoir.
3. Groundwater does not generally occur in underground streams, lakes or ponds etc rather it is found in soils and sands which are able to retain the water the way a sponge holds water.

4. About 2.78 million trillion gallons of groundwater which is about 30.10% of the world's fresh-water are estimated for the planet.
5. Out of total 349.0 billion gallons of freshwater, the US each day withdraws about 79.60 billion gallons of ground water.
6. About 1/4th of all rainfall in United States becomes the groundwater.
7. Streams and lakes are just like windows to the water table.
8. U.S. Geological Survey shows that about 30.0 percent of U.S. stream flow is from groundwater.
9. Less than 27.0 percent of the water used by Americans comes from underground sources.
10. In United States there is underutilization of ground water.

4. Water Pollution, Sources, Effects and Controls by Asha Gupta Manipur University

The main observations noted down after going through this paper have been listed below:

1. Water is one of the renewable sources found on the planet essential for sustaining chores of life like; food production, economic growth and general well-being in day to day life.
2. It is not possible to substitute water for its uses in many spheres of life.
3. Water is a divine and unique gift to mankind from nature.
4. Water is the natural resource capable of diversion, transport, storage, and recycling.
5. The resources of surface water and groundwater of a country always play a significant role in agriculture, hydropower, livestock production, industrial, forestry, fisheries, navigation and other similar activities.
6. The fresh-water ecosystems of the world comprise only about 1/2% of the earth's surface and have a volume of $2.84 \times 10^5 \text{ Km}^3$.
7. Rivers constitute an insignificant amount of water; only 0.01% of the waters of the earth occur in rivers.
8. Despite of these low proportions, running water is of great importance for living beings ^[4-7].

III. Objectives of The Studies

As water pollution is a global problem but major and burning problem in India. Some people consider it to be a normal course of action. They generally think that if not in water then where

they can throw the garbage elsewhere. Unaware of dreaded polluted water diseases which are threat to life during the present as well as for the coming generations, they keep on doing as usual. For the awareness of dreaded diseases owing to water pollution and maintaining the sanctity of nature, following major objectives of this paper are:

1. Chemistry behind the water pollution.
2. Chemicals responsible for toxicity in water – Diseases of polluted water.
3. Need for saving the underground water despite the plenty of surface water.
4. Withdrawal of ground water Vs recharge of aquifer.
5. Measurement of water pollution and remedial solutions for the same.

IV. RESEARCH METHODOLOGY

Methodology used was based on quantitative and qualitative analysis on the concerned problem. Identification & analysis of exact nature of problem from the related literature review. Going in depth of the concerned problem and finding the solutions for the same. Keeping in view the one of the most burning problem of the hour and finding ways to overcome that problem. Data collection related to the problem from the national statistics as well as global reviews. Including own views, findings and remedial solutions for the same.

V. RESULTS AND DISCUSSION

Different Chemicals found in water to inappropriate proportions make water polluted and unfit for drinking purposes and other household tasks like irrigation etc. Lack of chemicals and minerals in water is matter of concern while excess of such chemicals and minerals is also invitation to many hazards in normal life. Following is the detailed data of such chemicals responsible for water pollution which give invitation to many diseases:

1. Nitrates (NO_3^-), Nitrites (NO_2^-): They come from industry, agriculture, aquaculture, sewage etc. They are responsible for accelerated plant growth and algae in coastal water, which is deadly for the aquatic life. These algal blooms prevent the passage of sunlight into the water due to which photosynthesis is reduced, plant life underwater is adversely affected and hence amount of

dissolved oxygen decreases, which ultimately leads to death and decomposition of plants and animals underwater.

Related Diseases: In human bodies Nitrates (NO_3^-) get converted into nitrites (NO_2^-) by microbial flora of intestine. In this way methaemoglobin is formed when nitrites combine with hemoglobin and affects the oxygen carrying capacity of blood. The disease arose is called Blue Baby Syndrome or Methaemoglobinaemia which includes the symptoms of shortness of breath and blue coloration of skin. This disease is quite common in Rajasthan due to hard and saline water over there.

2. Toxic Metals: Heavy metals like, Mercury (Hg), Arsenic (As), Lead (Pb), Cadmium (Cd), Selenium (Se) etc can be present in the environment for decades and hazardous for aquatic life. Initially mercury is absorbed by algae in the form of methylmercury, fish eats algae, we consume fish or fish products, in this way mercury comes into our food chain. The excessive intake of such metals leads to biomagnifications, which is hazardous for us. The toxic elements and their affected areas (States/UTs/Districts) in India are shortlisted in Table-I as follows:

Toxic Elements	Number of Affected States	Number of Affected Districts
Nitrates (NO_3^-)	21	386
Arsenic (As)	21	153
Lead (Pb)	14	93
Cadmium (Cd)	09	24
Chromium (Cr)	10	30
Fluoride (F^-)	20	335
Salinity	15	212
Iron (Fe)	26	301

Table-I: Showing the data of affected states & districts in India with toxic elements present in polluted water

Related Diseases:

Mercury (Hg) has many toxic diseases related to lungs, kidneys, nervous system, digestive & immune systems, skin and eyes etc. Minamata disease in Japan affecting more than 2000 local residents was reported when methylmercury enriched liquid was discharged into Minamata River, thereby producing severe cases of paralysis, brain damage and incoherent speech.

Arsenic (As) toxicity produces vomiting, abdominal pain and diarrhea, muscle cramping and even death. Long exposure to Arsenic causes skin cancer, bladder and lungs cancer. Blackfoot Disease in Taiwan is the example of Arsenic poisoning.

Lead (Pb) poisoning causes nausea, anemia, vomiting, damaged kidneys and nervous system.

Cadmium (Cd) poisoning causes sensory disturbance, liver injury, shock and renal failure, vomiting, nausea, diarrhea etc. Itai-Itai disease in Japan is the example of lead poisoning.

Selenium (Se) if taken in excess through polluted water may cause difficulty in breathing, heart attack or heart failure, kidney failure etc.

3. Ammonia (NH₃) or Ammonium Ion (NH₄⁺): They come from industry, agriculture, urban areas and are harmful for environment as well as aquatic life as emission of ammonia leads to acid decomposition and excessive level of nutrients in soil, rivers etc.

4. Sulphates (SO₄²⁻) and Sulphides (S²⁻): They originate from mines and are hazardous for the environment as they mix with water to form sulphuric acid (H₂SO₄). This sulphuric acid comes in the rain water i.e. acid rain. So, they are responsible for acidification of water.

5. Phosphorus (P) and Phosphates (PO₄³⁻): They come from agriculture and urban areas, their adverse effects are similar to nitrates and nitrides. Detergents used in daily laundry purposes contain phosphates, so detergents are the major source of phosphates enriched water. Moreover detergents are non-biodegradable in nature, which is also a major environmental threat. These phosphates enter into plants through roots; causes chlorophyll destruction, denaturation of proteins and hence affects various metabolic processes.

6. Hydrocarbons (H_xC_y): Hydrocarbons in the form of crude oil, which comes from urban areas and industries, harmful for plants, birds and marine animals. Oil spills are shown to be

responsible for heart attack in fishes, destruction of thick hair that covers the entire body of mammals, which leads to more exposure and even to death. They are also called Oil Spills.

Oil spills are the release of liquid petroleum hydrocarbons into the atmosphere, they very much harmful for the aquatic life. When the oil spills occur it can cause the destruction in the insulating ability of fur in mammals and water repelling nature of the feathers in birds. This ultimately leads to *Hypothermia* and even death. Likewise it can cause heart attack in fishes.

As directly or indirectly we depend on plants, animals and aquatic life for our food requirements, so, these pollutants enter in our food chain also. The excessive amount of these elements may lead to biomagnification and bioaccumulation which may affect the central nervous system^[8-13].

VI. DISEASES CAUSED BY POLLUTED WATER

Around 250 million people worldwide get adversely affected by polluted water. Pathogens in polluted water cause numerous dreaded diseases. These diseases are categorized into following four main types^[14-16]:

1. Water Based Diseases: These are those diseases which are spread by organisms which develop in water. These organisms develop in water and then become human parasite. Examples are *schistosomiasis* and *dracunculiasis*. Both of these are infection diseases mostly found in African and Middle East countries.

2. Water Washed Diseases: These are the diseases caused by scarcity of clean water. Like trachoma; a bacterial infection in eyes, it's a leading preventable cause of blindness globally and scabies or the itch mite that burrows into skin and causes scabies. As per reports released by WHO in 2017, more than 2 billion people around the world do not get clean and safe water for drinking purpose. So, the probability of water washed diseases is quite high in those regions.

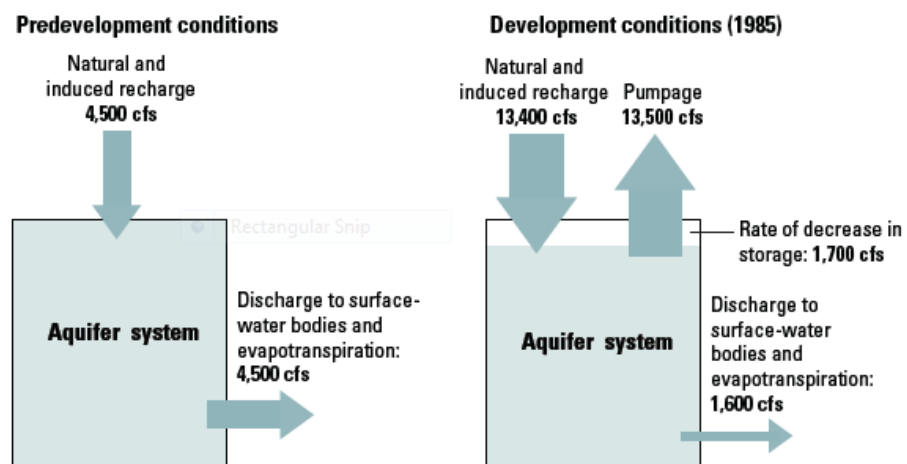
3. Water Borne Diseases: These are those diseases which come from drinking water containing infectious pollutants like bacteria or virus. Such bacteria or virus generally comes from human or animal waste. Examples of such diseases are typhoid, cholera and dysentery etc. These are very

common type of diseases which generally occurs when drinking water pipes get contaminated by the underground sewage pipes.

4. Water Related Diseases: These are the diseases spread by insect vectors like mosquitoes, flies etc. Examples of such diseases are dengue, malaria and filariasis etc. These are those diseases which if not controlled in time would lead to death.

VII. WITHDRAWAL RATE OF AN AQUIFER VERSUS NATURAL RECHARGE RATE

The bigger difference between the withdrawal rate and recharge rate is the major cause of lowering the water table. Undoubtedly, ground water, rain water, extra pumped water will ultimately seep/percolate through the pores of earth into the aquifer but this is a longer phenomenon. Natural recharge of the aquifer may take few days or even years depending upon the type of soil. In domestic wells we have seen the recharge and rise of water level in few hours. However, in most of the area, natural recharge rate is very small that's why it is advised to save the pumped out ground-water to maintain the water table beneath the earth. From the US Geological Survey Fact Sheet (Fig.-I), we can get an idea that pumping of ground water is 13,500 cfs while natural recharge rate is comparatively very lesser i.e. just 13,400 cfs. There is bigger difference of 500 cfs. If for years and years it will happen the obviously water table will decrease and in certain areas there will be no water to pump out for even drinking purposes.



and cleaning are not sufficient, now practical work out at ground level is required to control the situation. Let's take the pledge to do the needful practically in this regards ^[17-18].

VIII. SAVING THE GROUND WATER & CLEANING THE SURFACE WATER – THE ONLY SOLUTION

Many NGOs and Spiritual Missions are also taking keen interest in saving & cleaning of water. Actually, service to nature is the service to God. God has provided us this surrounding, beautiful earth and nature. It's our prime duty to save its sanctity. Let's not destroy it by polluting. Sant Nirankari Mission under the holy commandments of Satguru Mata Sudhiksha Ji Maharaj has taken this noble initiative to save water by starting a campaign across the country. On 26 Feb, 2023 project AMRIT was launched by the Nirankari Mission including over 1100 water bodies spread in around 730 cities. It covered 27 states and 15 main rivers. 457 river banks, 120 lakes, 307 ponds, 43 coastal areas, 26 water conservation spots and numerous drains, wells, mini dams etc were properly and thoroughly cleaned by the mission volunteers.

Likewise Sant Balbir Singh Seenchewal has spearheaded anti-river pollution campaign in Kapurthala in Punjab by resurrected 110 mile long 'Bein' River. Many eco-friendly tasks they have completed in recent years like setting up of sewage water treatment plants, growing plants to save the environment. This is the real service of nature and worship of God. If we love and preserve the nature created by God then it is equivalent to love The God itself.

Every one of us should think like that because pollution on earth is not due to any alien and someone like that rather it is due to all of us. If we will control, there will be no pollution in our surroundings. Self control is the first step in paradigm change in the society. To every action, there is equal and opposite reaction; lets save the nature, then nature will also save us. We will get fresh water, fresh oxygen and pollution free environment for healthy and prosperous life for ourselves as well as for our coming generations. Sometimes we think of living on the Moon and Mars etc, it's very good thinking. But let's first make this Earth a better place to live in, for all. We want to walk on Moon but don't know how to properly walk on this Earth. We belong to this beautiful earth, so it's our primary duty to save and beautify this planet.

IX. WATER RESOURCES MANAGEMENT

We are provided with very good sources of water in terms of rains, rivers, glaciers, lakes and springs etc. What we need is to manage them precisely and properly with the minimum wastage and maximum usage. Our cultivation is mainly dependent on rains and river water; if we manage these natural resources of water then we need not to worry in the times to come. Actually, with the passage of time demand of water is enormously increasing in comparison to rain water, we get. Now we are falling short in terms of rain water to meet the requirements for irrigation purpose:

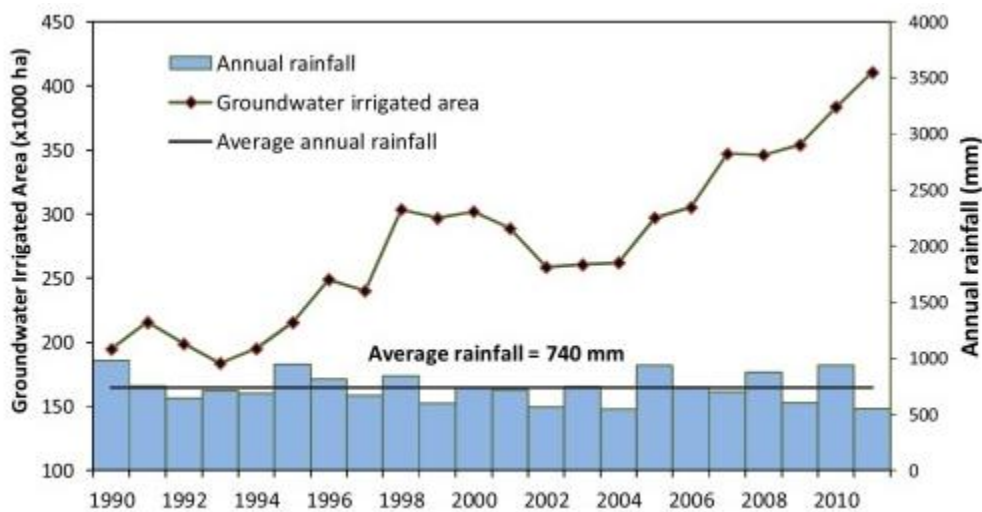


Fig.-III: Graphical representation between annual rainfall and annual requirement of water for irrigation

From the above data (Fig.-III) of annual rainfall (740 mm on average basis) and annual requirement of water for irrigation, it's very much clear that between the two there is a bigger difference. The bigger is the difference; more will be the serious matter of concern. To meet the requirement of irrigation, we have to pump out the ground water and hence the water table will be lowered. So, along with the management of water resources, we have to manage our crop cultivation system also. Manage cultivation of those crops which require more consumption of water. Let the soil also relax a bit to regenerate its fertility potential with the management of crop cultivation [19-20].

X. MEASUREMENT OF WATER POLLUTION – FIRST STEP FOR REMEDIAL ACTION

Water pollution can be easily determined and then tackled with remedial effects. The main types of measurements in determining the water pollution are of following three broad types:

1. Physical Measurements: It includes the measurement on:

- i) Temperature of water sample
- ii) Turbidity and total suspended particles in water sample.

2. Chemical Measurements: It includes the measurements on:

- i) Chemical Oxygen Demand (COD); it is basically the oxygen equivalent of organic matter that can be oxidized by strong oxidizing agents.
- ii) Biological Oxygen Demand (BOD); it involves the measurement of dissolved oxygen utilized by micro-organisms for the biochemical oxidation of organic matter.
- iii) pH- Value of water sample.
- iv) Oil, Nutrients & Metals present in water sample.

3. Biological Measurements: It includes measurements on:

- i) Presence of microbes in water
- ii) Total nutrients that aquatic lives are getting from water sample
- iii) Aquatic habitat present in water sample

All these measurements are easy and convenient, so, after the determination of level of water pollution immediate remedial steps should be taken by the Governments as well as the individuals to curb the menace of water pollution.

As for as the remedial steps are concerned some significant control measures are given below:

1. Growing More Plants: Plants are the natural filters and natural air conditioners; they provide us oxygen to live, without which we cannot survive more than few minutes. We give them carbon dioxide to live; they give us oxygen to live. For plants I can say that, ***“I can’t live without you”***

2. Start Doing Rather Than Just Thinking

Now we are neck-deep into this problem of pollution. Just by dreaming of doing better, lectures on pollution and teaching only we can't solve the problem; now actions are required from the individuals. Just thinking big is not required; doing big is the need of the hour now.

3. Recycled Industrial Waste

Industries are the major source of pollution. Many point sources and non-point sources are linked to industries itself. Moreover we can't control the pollutant wastes coming out from the industries rather this waste can be recycled before entering into the sink (earth, rivers & environment etc). This recycled waste will be less harmful than it was originally. More precisely, any industrial waste whether partially treated or fully treated should not be discharged into any water body because some radioactive wastes are fully hazardous even after recycling. So, absolutely prohibition is a mandatory step to perform.

4. Public Awareness & Strictness

Un-aware public must be made aware of environment crises and aware off persons must be dealt with strictness so that we can create pollution free environment. It's not only our social or moral duty rather it's our spiritual duty also to protect our environment we have been provided by the God. Our physical health, mental health is directly proportional to our healthy atmosphere, so, it should be neat & clean in every aspect. To live longer, to live healthier, we always need healthy organs, healthy environment and healthy food; this is possible if and only if we have pollution free surroundings.

XI. CONCLUSION

The Water (Prevention & Control of Pollution) Act was enacted in 1974 then amended in 1988, now it was last amended in 2003. Its 2023 now, so, it's urgently needed to be amended again so that as per the need of the hour new guidelines should be included for the better outcomes. Saving of groundwater and cleaning of surface water is the utmost need of the hour. We have plenty of water in ocean, rivers and glaciers but still there is scarcity of fresh drinking water and unpolluted water for irrigation. For that reason pumping out of ground water has lowered the water table. If we will keep on water-pumping like this then in the coming years we will not get even drinking water in many regions in India. Pollution free surface water is to be maintained, this will prevent living beings from life hazards, less pumping out will maintain the water table and saving of nature will automatically occur likewise. Along with big dreams big doing is

required now. Change your life style, change your thinking and preserve the nature. If we will save the nature, nature will save us and our coming generations.

XII. LIMITATIONS

On water pollution every river, every water reservoir has its own level of pollution, so, same methodology cannot be applied for every water bodies. Some water bodies have one toxic metal in excess some has other, so, we cannot apply same procedure to tackle the problem. Many regions/states of the country has water table above par, they think they need not to apply the same saving approach as the other people of other regions are doing. Moreover, every individual thinks that if I'll not do then what will be the loss to this whole wide world but forgets that if everyone will think like that then what will be the situation.

Everything has its limitations. The main limitation is that when we just think off and give lectures but do not work on the same on ground. Same is the case in this regards also. We sometimes do not pay heed to what the nature demands from us. The day we will adopt all these Dos and Don'ts, the earth will be a better place to live in; not less than a heaven.

XII. SCOPE FOR FURTHER RESEARCH

Water pollution is a global problem. It's not being curbed so far, so, it has a very much further scope of research, new innovative techniques to tackle it. Desalination of sea-water with any economical and convenient methodology may be useful to remove the scarcity of water. We have plenty of water in the ocean but it's not fit for drinking and irrigation etc. Once we develop a methodology to desalinate the sea water easily and conveniently then to greater extent the problem would be solved. Developing innovative water treatment system, new research in rainwater harvesting etc would be a milestone in the research in this field. In nutshell, the scope of new research in this field is very much.

XIII. REFERENCES

- Adetunde, L.A. and Glover, R.L.K. (2010). Bacteriological Quality of Borehole Water Used by Students' of University for Development Studies, Navrongo Campus in Upper-East Region of Ghana. *Current Research Journal of Biological Sciences*. 2(6):361-364.
- Baig, J.A., Kazi, T. G., Arain, M. B., Afridi, H. I., Kandhro, G.A., Sarfraz, R. A., Jamali, M. K. and Shah, A. Q. (2009). Evaluation of arsenic and other physico-chemical parameters of surface and ground water of Jamshoro, Pakistan. *Journal of Hazardous Materials*. 166, 662-669.
- Bu, H., Tan, X., Li, S. and Zhang, Q. (2010). Water quality assessment of the Jinshui River (China) using multivariate statistical techniques. *Environ Earth Sci*. 60, 1631-1639.
- Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and Smith, V.H. (1998). Non point pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*. 8: 559-568.
- Chinnasamy, P., Maheshwari, B and Prathapar, S. (2015). Understanding Groundwater Storage Changes and Recharge in Rajasthan, India through Remote Sensing. *Water* , 7: 5547-5565 <https://doi.org/10.3390/w7105547>
- CPCB Report. (2013). Status of Water Quality in India, 2011. Monitoring of Indian National Aquatic Resources, Series: MINARS/35/2013-14. pp. 1-212.
- Dovjak, M., Kukec, A. (2019), "Health Outcomes Related to Built Environments", *Creating Healthy and Sustainable Buildings*, Cham: Springer International Publishing, pp. 43-82, doi:10.1007/978-3-030-19412-3_2, ISBN 978-3-030-19411-6, S2CID 190160283, retrieved 2022-08-10.
- Johnson, M.S., Buck, R.C., Cousins, I.T., Weis, C.P., Fenton, S.E. (2021). "Estimating Environmental Hazard and Risks from Exposure to Per- and Polyfluoroalkyl Substances (PFASs): Outcome of a SETAC Focused Topic Meeting". *Environmental Toxicology and Chemistry*. 40 (3): 543-549. doi:10.1002/etc.4784. PMC 8387100. PMID 32452041.
- Kjellstrom, T., Lodh, M., McMichael, T., Ranmuthugala, G., Shrestha, R., Kingsland, S. (2006). *Air and Water Pollution: Burden and Strategies for Control*. PMID 21250344.

- Knight, K. (2021). "Freshwater methamphetamine pollution turns brown trout into addicts". *Journal of Experimental Biology*. 224 (13): doi:10.1242/jeb.242971. ISSN 0022-0949.
- Mian, I. A., Begum, S., Riaz, M., Ridealgh, M., McClean, C. J. and Cresser, M. S. (2010). Spatial and temporal trends in nitrate concentrations in the River Derwent, North Yorkshire, and its need for NVZ status. *Science of the Total Environment*: 408, 702–712.
- Rajendra P. Sishodiaa, Sanjay Shuklaa, S. , Wendy D. Grahamb, Suhas P. Wani, Kaushal K. Garg (2016). Bi-decadal groundwater level trends in a semi-arid south indian region: Declines, causes and management. *Journal of Hydrology: Regional Studies*. 8:43-58. <https://doi.org/10.1016/j.ejrh.2016.09.005>
- Ramadhani Mussa. K., Chikira Mjemah. I. and Lazaro Machunda, R. (2021). Natural Groundwater Recharge Response to Climate Variability and Land Cover Change Perturbations in Basins with Contrasting Climate and Geology in Tanzania. *Earth*, 2:556-585. <https://doi.org/10.3390/earth2030033>
- Ramakrishnaiah, C.R., Sadashivalah, C and Ranganna, G. (2009). Assessment of water quality index for groundwater in Tumkur Taluk, Karnataka State. *Indian J. Chem.* 6: 523-530.
- Rodhe, W. (1969). Crystallization of eutrophication concepts in North Europe. In: Eutrophication, Causes, Consequences, Correctives. *National Academy of Sciences, Washington D.C.*, Standard Book Number 309-01700-9, 50-64.
- Steiner, T.S., Samie, A. and Guerrant, R.L. (2006). Infectious diarrhea: new pathogens and new challenges in developed and developing areas. *Clin. Infect. Dis.* 43:408–410.
- "Summary of the Clean Water Act". *Laws & Regulations*. EPA. October 22, 2021.
- Wang, X., Han, J., Xu, L. and Zhang, Q. (2010). Spatial and seasonal variations of the contamination within water body of the Grand Canal, China. *Environmental Pollution*. 158: 1513–1520.
- Water Management Forum (2003). Inter-basin transfer of water in India-Prospects and Problems. *The Institution of Engineers (India)*, New Delhi.
- Williamson, A.K., and Grubb, H.F., (2001), Ground-water flow in the Gulf Coast aquifer systems, south-central United States: U.S. Geological Survey Professional Paper 1416-F, p. F1-F173.