Conversion of Mine Water to Potable Water

Sunil Kumar Srivastava
AISECT University, Hazaribag (Jharkhand) India.

ABSTRACT
It is very well known that there is acute shortage of good quality drinking water. The quality of water which the common man drinks is not at par with the Indian standard specifications for drinking water i.e., IS-10500. The mine water coming out from Jharia coal fields, Raniganj coal field, Central coal field, Talcher coalfield, Northern coalfield, North Eastern coal field and Western coalfield,when characterized revealed that in most of the cases, higher values of TSS, TDS, Fe, Mn, Cl, F, SO_4, Cu, As, Hg, CN, Ni, Cr, Al, Zn, Nitrate, Hardness, Phenol, Oil & grease and coliform were observed as compared to the respective values givenin IS-10500. When this water were treated with optimum dose (concentration and time) of ozone, the results were encouraging and the higher values of the above parameters were reduced and found to be at par with IS -10500. Since this work was carried out for a private party on payment basis, the details of the data generated at different doses of ozone (concentration and time) cannot be provided. The present paper deals with the basic principles/science behind such a reduction i.e., conversion of mine water to potable water.

Keywords- Granular Active Carbon Filter, (GACF) Dissolved Organisation, (Doc), Total Dissolved Solid (TDS) etc

I INTRODUCTION

Providing good quality drinking water to all human being is the basic need for all the government of any country. If mankind are not getting good quality potable water, they are suffering from various water borne diseases e.g., if the pH of water is beyond the recommended range, the water will affect the mucous membrane and/or water supply system. If the TDS is not in the recommended range then palatability of water decreases and may cause gastro-intestinal irritation. Similarly chloride, beyond the limits, affect taste, corrosion, and palatability. Taste of water becomes unpleasant if alkalinity data is not in the range. Due to high calcium, hardness, encrustation in water supply structure and adverse effects on domestic use are distinctly visible. Magnesium hardness affects heart beat and ultimately leads to heart attack. More sulphate causes gastro intestinal irritation when Na/Mg are present. Higher nitrate is responsible for Methanemoglobinemia. Oxygen carrying capacity becomes less. More ammonium converts into urea. Causes stone formation in gallbladder, kidney. Coliform is the root cause of large number of diseases viz Ecoli, Bcoli, Jaundice, diohrrea, dyssentry, Giardia, Amoebia etc. Healthy human being of any country makes the nation healthy. Keeping the above in view, we have carried out the work on conversion of mine water to potable water.

II EXPERIMENTAL

The ozone was prepared by silent electric discharge method in a ozone generator. The ozone coming out from the generator was subjected to flow meter followed by passing it from bottom of a graduated transparent long & wide column which contain mine water.System was continuous. The outlet at the top was connected to sand filter and then Granular Active carbon filter. The treated water coming out of the filters was analysed and the results were compared with the respective data of raw mine water. The filters were cleaned after each experiment. Filters contained solid materials/precipitates. The dose was fixed and to each fixed dose, time of interaction of ozone with mine water was varied, and vice versa. For a given time of interaction of O_3 with mine water, the system was preset. Similarly optimum concentration of ozone dose was determined. The best results were obtained when both optimum concentration andoptime time were applied.

III RESULTS AND DISCUSSION

Table 1 summarizes the physico-chemical characteristics of some of the mine water. Table-2 compiles the data on indian standard specification for drinking water IS-10500 for ready comparison. It is evident that in some or most of the cases TSS, TDS, Hardness, Fe, Mn, Cl, F, SO_4, NO_3, Cu, As, Hg, CN, Ni, Cr, Al, Zn, Phenol, oil & grease, coliform and organic are higher than the corresponding values given in Table-2, making the mine water unfit for drinking purposes. Ozone as disinfectant was tried for the first time in 1893. But in India, its use is practically nil. In Dhanbad and nearby areas, anyone who stays beyond six months becomes patient of acute gastritis. The reason is, presence of Giardia, amoebia etc. in water. Frequently the residents suffer from urinary Tract Infection- Ecoli, Bcoli and also 58% of the residents suffer from Asthama due to Pollen grains, Algae, Fungi, and different types of mites i.e., due to air pollution.

Table 1
Indian standard specifications for Drinking water IS – 10500
1992→(1993)

Sl No.	Parameter	Desirable	Extended up to
1	Colour(Max) Hazen units	5	25
2	Turbidity(NTU) Max	5	10
3	pH	6.5-8.5	9.2
4	Total hardness as $CaCo_3$(Max)	300	600
5	Calcium(Ca) (Max)	75	200
6	Magnesium (Mg) (Max)	30	100
7	copper (Cu) (Max)	0.05	1.5
8	Iron as Fe (Max)	0.3	1.0
9	Manganese (Mn) (Max)	0.1	0.3
10	Chlorides as cl (Max)	250	1000
11	Sulphates (SO_4) (Max)	200	400
12	Nitrates (NO_3)	45	100
13	Fluoride (Max)	1.0	1.5
14	Phenolic compounds (C_6H_5OH) Max	0.001	0.002
15	Mercury(Hg) Max	0.001	No
16	Cadmium(cd) Max	0.01	No
17	selenium(Se) Max	0.01	No
18	Arsenic (As) Max	0.05	No
19	cyanide (CN) Max	0.05	No
20	Lead (Rb) Max	0.05	No
21	Zinc(Zn) Max	5.0 15	
22	Anionic detergents (MBAS) Max	0.2	1.0
23	Chromium (Cr^{+6}) Max	0.05	No
24	PAH (Max)	-	-
25	Mineral oil (Max)	0.01	0.03
26	Residual Free chlorine (Max)	0.2	-
27	Pesticides	sent	0.001
28	Radioactive αemitters Bq/l Max β emitters Pci/ Max	-	0.1
29	Odour	Unobjectionalble	
30	Taste	Agreeable	-
31	Dissolved solids (Max)	500	2000
32	Alkalimity Max	200	600
33	Aluminium (Al) Max	0.03	0.2
34	Boron(B) Max	1	5

Table 2

General standards for discharge of Environmental pollution Effluents

S.no.	Parameter	Inland surface water	Public sewers	Land of irrigation	Marine/coastal areas
1	colour & odou				
2	Suspended soid mg/l max	100	600	200	Process waste water – 100 cooling water- 10% above total suspended matter of influent
3	Particle size of suspended solid	- 850μ 15 sieve	-	-	Flotable – max 3mm setueable –max 856μ
4		5.5-9.0	5.5-4.0		5.5
5	Temperature	Shall not exceed 5°c above receiving water temp	-	-	Shall not exceed 5°c above receiving water Temperature
6	Oil & grease mg/l max	20	10		
7		mg/l 1.0	-	-	1.0
8	Ammoniacal Nitrogen as N mg/l max	50	50	-	50
9	Total Nitrogen as N mg/l	100	-	-	100
10	Free Ammonia as NH_3 mg/l max	5.0	-	-	5.0
11	Biochemical Oxygen Demand 3days at 27 °c	30	350	100	100
12		)	-	-	250
13	As mg/l max	0.2	0.2	0.2	0.2
14	Hg mg/l max	0.01	0.01	-	0.01
15	Pb mg/l max	0.1	0.1	-	2.0
16	cd mg/l max	2.0	1.0	-	2.0
17	Cr^{+6} mg/l max	0.1	2.0	-	1.0
18	Total Cr mg/l max	2.0	2.0	-	2.0
19	Cu mg/l max	3.0	3.0	-	30
20	Zn mg/l max	5.0	15	-	15
21	Se mg/l max	0.05	0.05	-	0.05
22	Ni mg/l max	3.0	3.0	-	50
23	Cn mg/l max	0.2	2.0	0.2	0.2
24	F mg/l max	2.0	15	-	15
25		5.0	-	-	-
26	Dissolved Phosphates (p) mg/l max		-	-	5.0
27	Phenolic compounds as	1.0	5.0	-	5.0
28	Radioactive materials α emitters microwave mg/l max	10^{-7} 10^{-6}	10^{-7} 10^{-6}	10^{-8} 10^{-7}	10^{-7} 10^{-6}
29	β emitters microw mg/l max	90% Survival of fish after 96 hrs is 100% effluent	90%survival of fish after 96 hrs is 100% effluent	90% survival of finish after 96 hrs is 100% effluent	90% survival of fish after 96 hrs in 100% effluent
30	Mn mg/l				
31	Fe mg/l	3	3	3	3
32	V mg/l	0.2	0.2	0.2	0.2
33	Nitrate N mg/l	10	-	-	20

These standards shall be applicable for industries, operation or process other than those industries, operation or process for which standards have been specified in schedule of Environment protection Rules 1989.

As mentioned above, a number of parameters are found to be higher than the prescribed limits. Let us understand how treatment of mine water with different doses and for various timings reduces the higher values of above parameters to the prescribed limit, one by one.

(a) Organic Matter:-

Natural organic matter (NOM) is measured as dissolved organic carbon (DOC) usually in concentrations 0.2 to >10mg/l, creates odour & taste problems, Organic disinfection by-products (DBP's) formation supports bacterial regrowth in distribution system. DBP's are mainly formed during the reaction between organicmatter (OM) and ozone (O_3), here disinfectant. These organic DBP's do not have any risk of violation of drinking water standards. Pesticides are also organic matter e.g., diaznion, diemethoate, pantheon-methyl, diuron, linuron, methabenzthiazuron, metabromuron, MCPA, MCPP, Chlortoluron, isoproturon,metaxuron,vinclozolin etc. Odour and taste forming compounds are present in raw water, can also be formed during water treatment, and may be derived from the decomposition of plant matter, as also due to activity of living organism present in water. Present day chlorine treatment leads to unpleasant taste and odour. Ozone is more effective in removing unsaturated hydrocarbon forming insoluble ozonides. Algae produces Geosmine and 2-methyl is oborneol (MIB), resistant odorous compounds present in water can also be removed by ozone.

By ozonation OM is partially oxidised to –

(i) Higher aldehydes, ketones and carboxylic acids which are insoluble in water and can be filteredout,

(ii) Form polar molecules containing hetero-atoms having loan pair of electrons which has ability to form chelates/metal complexes with cations. Anions are associated with the metal chelates to neutralise the cationic charges,

(iii) If bigger molecules of size 10-2000$\dot{A}$ are formed resulting in turbidity/colloidal solution, as also TSS, ozone enhances coagulationprocess. These precipitates, that meansinsolubles can be fittered out and

(iv) The coliform, viruses, Giardia, amoebia, Ecoli, Bcoli, bacteria, living organisms, microbiological agents, protozoans, cryptosporidium etc are oxidised to higher aldehydes, ketones and carboxylic acids which are insoluble in water and can be filtered out.

(b) Total Dissolved Solid (TDS),Cations and Anions: -

TDS contain Inorganic as well as organic. Ozonation of OM has been discussed in detail above. Inorganic matter contains cations such as Ca, Mg, Na, K etc which on oxidations forms metal chelates and insoluble oxides and can be filtered out. Anions present e.g., CO_3, HCO_3, Cl, SO_4,NO_3, are associated with metal complexes to neutralize cationic charges as discussed in the previous section. The Tolerance limits for Ca, Mg, Fe, Mn and sulphate are 75,30,0.3,0.1 and 150mg/l respectively.

(c) Oil & Grease, TSS and Coliform:-

Oil and Grease are organic matter and its inter actions with ozone has already been dealt in organic matter section of results and discussions.Similarly precipitation of total suspended solids using ozones coagulating properties has also been discussed in organic matter section of results and discussion.

(d) Advantage of ozone over chlorine:-

(i) Ozone is 25 times more effective than HOCl (hypochorous acid), 2500 times more effective than hypochlorite (OCl) and 5000 times more effective than chloramines (NH_2Cl). This is measured by comparison of CT constants i.e, the concentration and the time needed to kill 99.9% of all micro-organisms. Chlorine reacts with organic materials to form chlorine containing organics such as $CHCl_3$, CCl_4, CH_3Cl and others generally known as Trihalomethanes (THM's).

(ii) Ozone reacts with organics to break them down into simpler compounds these do not readily break down all the way to CO_2 with just O_3, but if subjected to bacterial degradation on activated charcoal, they will be removed. This water can be later treated with a low level of Cl_2 say 0.2-0.3 ppm to maintain sanitation in the distribution system. This way no THM's will be formed. These have been implicated as carcinogens in the development of kidney, Bladder and colon cancer. The limit of THM's in potable water is 0.01 ppm.

(iii) Ozone does not react significantly with THM's as they are more resistant to oxidation- it takes a very long time to achieve complete oxidation. THM's are removed as a result of physical sparring by the aeration action of ozone/air mixture.

(iv) Some of the properties of ozone and chlorine are summarized below as available in literature.

Action in water	Ozone	Chlorine
Oxidation Potential (Volts)	2.07	1.36
Disinfection (Bacteria & viruses)	Excellent	Moderate
Environment friendly	Yes	No
Color Removal	Excellent	Good
Carcinogen formation	Unlikely	Likely
Organic oxidation	High	Moderate
Microflocculation	Moderate	None
pH effect	Lowers	Variable
Water half life	20min	2-3 hours
Operational Hazards(Skin toxicity)	Moderate	High
Operational Hazards (Inhalation Toxicity)	High	High
Complexity	High	Low
Capital cost	High	Low
Monthly use cost	Low	High

(e) Other Properties

Ozone	Chlorine
Ozone is toxic at 100 ppt level Ozone is generated in Premises	It is not only toxic but poisonous also Chlorine is stored in high pressure containers in the premises & is hazardous
Ozone degrades all organic substances into harmless ashes and does not leave any other product than oxygen.	Chlorine when mixed with body fluids and perspiration, will form chloramines that will cause eye irritation and are carcinogenic in nature
Ozone becomes less expensive due to an increase in efficiency and lower energy consumption	The cost of chlorine is constantly increasing and it has become quite expensive.
Ozone does not require pH control	Chlorine needs pH control (7.0-7.4) for reliable results.
Ozone is an excellent deodorizing agent for many substance e.g., H_2S, NH_3, smokes, cooking smells, paints etc.	Chlorine does not have such effects.
Ozone is 600 to 3000 times more active is destruction of bacteria and viruses than chlorine. Ecoli is killed within 5 seconds at a concentration of 1 mg/l. Even the cysts and spores cannot resist ozone.	For killing Ecoli, chlorine requires 15000 seconds at a concentration of 1mg/l

(f) Reactions involved during ozonation of Mine water:

(i) Ozone reacts with water to produce OH^- :

$$O_3 + H_2O \rightleftharpoons 2OH^- + O_2$$

When mine water is kept, it is in chemical equilibrium. When OH^- is added to the system in equilibrium, as per Le Chattelier's principle. "The concentration stress on an added reactant/product/substance is relieved by net reaction in the direction that consumes the added substance, means OH^- has to be consumed.

$Ca^{2+} + 2OH^- \rightarrow Ca(OH)_2$

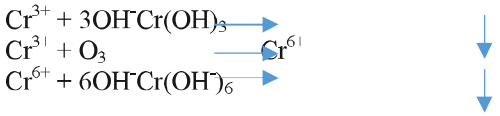
$Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2$

$Fe^{2+} + O_3 \rightarrow Fe^{3+}$

$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$

$Mn^{2+} + O_3 \rightarrow Mn^{4+}$

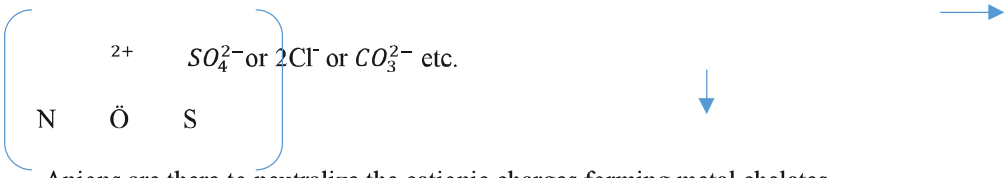
$Mn^{4+} + 4OH^- \rightarrow Mn(OH)_4$



(ii) Formation of Metal Chelates:

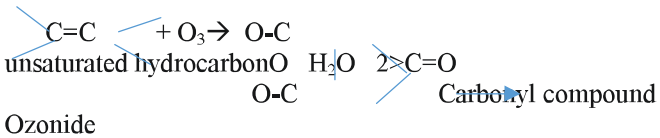
Heteroatoms with lone pair of electrons behaves like ligand and comes in contact with

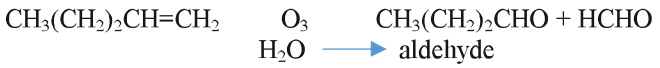
M^{2+}cations. – – and/or – – and/or – – + M^{2+}

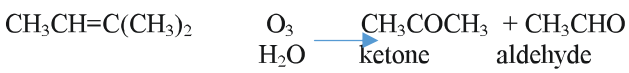


Anions are there to neutralize the cationic charges forming metal chelates

(iii) Reactions with organic matter, coliform, oil & grease etc.

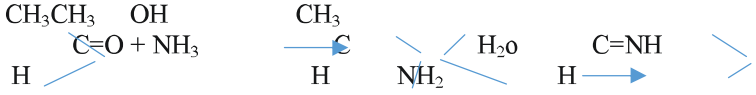


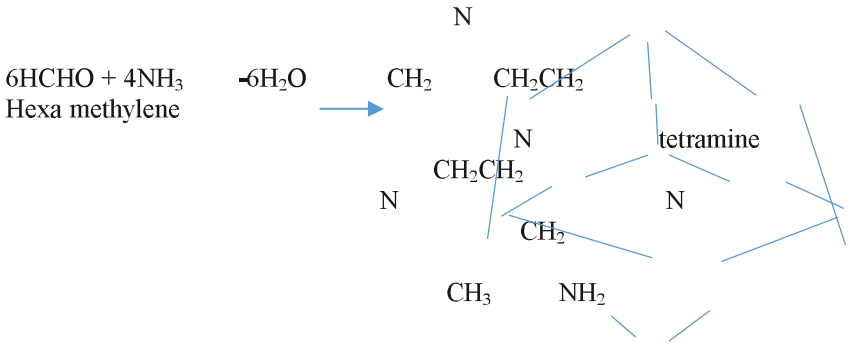


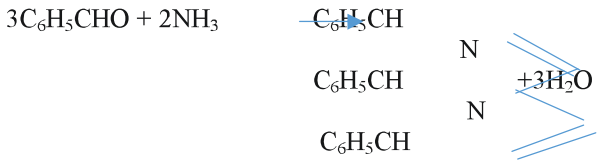


The first four aliphatic members are soluble in water due to intermolecular hydrogen bonding with water molecules. But here in this case the number of aliphatic members are more than four and bigger in size. The non-polar part of the molecule predominates there and reduces the solubility in water. The higher members are practically insoluble in water.

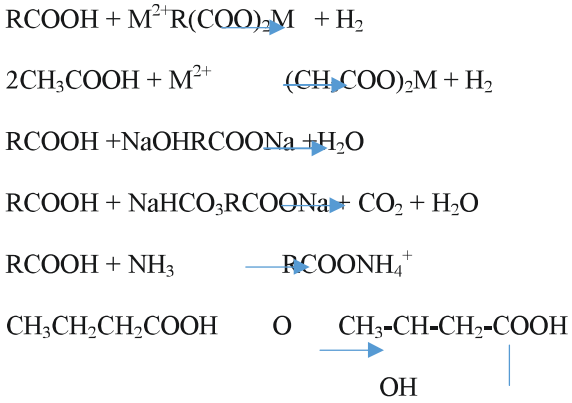
(iv) Ammonia reacts with aldehydes and ketones to form imines:







(v) Reaction with carboxylic acid :-



IV CONCLUSION

It can be seen from the above discussions that after optimizing CT doses of Ozone, in above mine water samples, the out of range (with respect to IS-10500) parameters can be brought to thin the range and then the resultant waters can be used for drinking purposes. More research is needed using samples of mine waters from all over India. Use of age old technology by conversion of soluble bicarbonates into insoluble carbonates may also be tried before ozone treatment where hardness is much more. Similarly permuitit method, calgon process and or Ion exchange resins may be used for such very high hardness mine water before ozone treatment, to get the desired result.