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MINE- PIT WATER TREATMENT FOR WATER SUPPLY IN DROUGHT AFFECTED AREAS

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Abstract
Coal mining activities include preparation of surface, excavation, extraction of coal, overburden storage & stabilization, backfilling and plantation. Of these operations complete backfilling of mined out area is seldom achieved. This leaves huge craters or unfilled pits within mine leases. These abandoned mine pits hold mine pit-water, rainwater and run-offs from mined area. Mine pit water in coal mining areas can be acidic and presence of a few health related parameters has been reported. This is one of the reasons of their unsuitability as water supply sources. Feasibility of treatment of mine pit water to remove health-related parameters by conventional and package treatment plants cannot be denied. Such need based treatment will enable to utilize these abandoned sources at least during drought –like situations. The paper addresses the feasibility of using the mine pit water for domestic use.

Keywords: Mine pit water quality, water treatment for fluoride removal, package treatment plants, etc.

Introduction

Chandrapur district of Maharashtra is facing unprecedented water shortage due to insufficient rainfall since year 2009. There is particular concern for supply of potable water to villages. Option of drinking water supply by tankers to affected villages may not be possible because usual sources for tanker-supply also have dried. Industrial activity also is likely to be curtailed due to shortage of water. Some of the industries in this district are water intensive e.g. thermal power plants, paper mills, textile units, etc. Coal and limestone mining in Warora, Yavatmal, Wardha and Chandrapur has been steadily intensified to meet growing demand of coal and limestone. Coal mining (open cast and underground) invariably intercepts ground water table (G.W.T.) necessitating de-watering during active mining. Thus de-watering of mines is an intrinsic part of open and underground mining operations. Two major impacts of coal mining are i) depletion of G.W.T. in the nearby areas and ii) discharge of mine pit water, commonly called 'acid mine water' within proximity of open cast or underground mines. In addition, indirect impact of mining is worsening of ground water quality in the mine- fringe areas due to continued water withdrawal. Rate of dewatering depends on physiography and drainage of the area, geology, hydro geological and aquifer parameters etc. A study was conducted by central ground water board (C.G.W.B.) regarding impact of dewatering of Padamapur, Durgapur open cast coal mines in Wardha coalfields. Study area was 104 km^2.

Survey had shown that i) mine pit -water -pumping was @ 2.275260 Mm^3/year from Padmapur O.C and @ 5.487Mm^3/year from Durgapur open cast mine. Total withdrawal from 104 km^2 per year was @ 7.76226 Mm^3. ii) Ground water recharge within 104 km^2 area as per Ground Water Estimation (GWE) Committee 1997 norms was 15.75 Mm^3/year since rainfall was normal rainfall (1200mm/year), iii)Draft of ground water by mining under normal rainfall conditions was about 49.3 per cent of total recharge, iv) ground water consumption for domestic, irrigation and industrial uses in 104 km^2 area was taken as 10 per cent in

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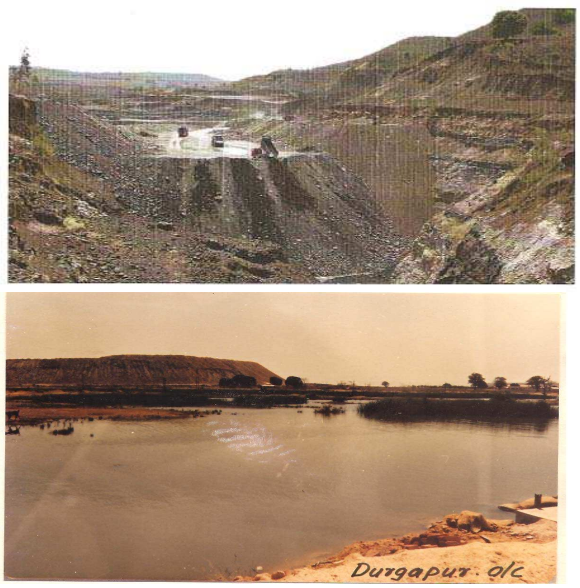
absence of authentic data for the area, v) total annual draft was 59.3 per cent of annual recharge.

Prima-facie it may appear that withdrawal of water has not altered the 'safe' category of ground water development. However, the study had shown that ground water table in the nearby villages had progressively declined. Most conditions e.g. physiography and drainage of the area, geology, hydro geological and aquifer parameters in Chandrapur are identical in the district. Aquatic systems and water management practices in other mines in the district are similar.

Activities during mining include site preparation for mining, excavation, extraction of coal, overburden - storage & stabilization, backfilling and plantation. Of these operations, backfilling is seldom complete because backfilling material is inadequate. This leaves huge craters Figure 1(a) or unfilled pits within mine leases. These abandoned mine pits hold both mine pit-water and rainwater including run-offs from mine area Figure 1(b).



(a)
(b)

Figure 1: Mine-Pit

In case of underground mines water is stored in 'goaf'. Thus, three types of water sources exist in any working or abandoned mine. They are i) stored water in open cast mine pits, ii) goaf- water and iii) flowing mine pit water. These are almost perennial sources but available quantities can vary.

Water quality in mine areas

Water samples were collected from coal mining areas and were analyzed as per standard methods [1]. Also substantial water quality data from active and abandoned mine in Chandrapur area has been collected from EIA reports of different mines, annual Environmental Statements of a number of WCL mines Kanhan, Chandrapur and Wani coal fields and from the literature. Table 1 includes summary of water quality in coal mine areas.

Mine pit water quality mentioned in Table 1 when compared with IS 10500-2001 for drinking water [2] indicates that priority of treatment will have to be for removal/reducing of health related ingredients like arsenic, fluoride, heavy metals etc, and disinfection. Next need will be to make the water aesthetically acceptable by reducing hardness, chloride, iron, etc. Fluoride and arsenic are cumulative toxic materials. Therefore their removal is imperative and inevitable.

Purpose of paper

It is apt to enquire into the possibility of using mine pit water for domestic use particularly during drought-like conditions in Chandrapur where water is available but needs treatment to be useful. Thus a few treatment options are presented in this paper to render mine water acceptable for either for domestic or drinking purpose.

Background

Water supply sources are categorized in four classes as. They are 1) unfiltered public water supply after disinfection 2) public water supply with approved treatment equal to coagulation, sedimentation & disinfection 3) not fit for human consumption, fish or wild life and 4) agriculture, industrial cooling and process water. Mine pit water can be termed as 'class 2' water. A survey of recent publications regarding treatment options has shown that limestone neutralization and phosphates amendment of mine pit water has been studied by Neil et. al.[3] for removal of mine-pit- water toxicity. They have reported the results of bio-assays of mine pit lake water remediate with limestone and phosphorus. They have reported that concentration of heavy metals reduce from 98 to 14 per cent and also reduced toxicity to the test species. Shan Ai-qin et. al. [4] have suggested methods of treating acid mine water by goaf. Goaf contains many stones and solid material with interstices which filter and probably adsorb toxic material. Such goaf water can be utilized. Zhong-ning Zhou et. al. [5] also have suggested similar method. Removal of heavy metals from acid mine drainage (AMD) using coal fly ash, natural clinker and synthetic zeolites have reported by C.A.Rios et. al.; Gitari et. al., and Lal et. al. [6, 7 & 8]. Similarly Barnaby J.Watten et. al. and Kalin et. al. [9, 10] have suggested pulsed- bed –treatment with CO_2 of acid mine drainage. CO_2 accelerates lime stone dissolution. Electrochemical treatment for acid mine water suggested by Chartrand and Buance [11]. Johnson et. al.; Kalin; McCullough and Santos et. al. [12, 13, 14 & 15] have also suggested the similar kind of treatments for mine-pit water. These methods rely on pH amendment of mine pit water.

Arsenic as an element is insoluble in water. Presence of arsenic in water samples within coal mining area indicates contamination of a source by mine water in which it is in colloidal state. It can be removed during conventional water treatment including alum coagulation & flocculation, settling and filtration. If arsenic is organically bound then it has to be first oxidized and then removed by activated carbon adsorption.

Suggested Treatments

Water quality requirement for domestic water supply is given in Table 1. Table 1 also shows that mine water proposed to be used for drinking, will require treatment for correction of pH, acidity and hardness in order of preference. Special treatment will be required for removal of iron, manganese and heavy metals along with arsenic & fluoride.

Table 1: Water quality in coal mine areas

Sr. No.	Parameters	Unit	IS-10500-2001 Drinking water		Sampling stations			
			Desirable	Permissible	Kanhan		SECL	Chandrapur
1	Ambient Temperature	°C			-	-	-	32
2	Colour	Hazen	5	25	Colourless	-	Colourless	Colourless-red
3	Odour		UO	UO	-	-	-	UO
4	Taste		AG	AG	-	-	-	AG
5	Turbidity	NTU	5	10	5	1 - 8	< 1	< 1
6	pH		6.5-8.5	NR	6.9 - 7.1	3.1- 6.5	6.9	7.1
7	Dissolved oxygen	mg/L	*	*		-	-	1.9
8	BOD	mg/L	*	*	-	-	-	2.5
9	COD	mg/L	*	*	-	-	-	8
10	Electrical conductance	µS	*	*	710 - 944	1200-2800	270	3100
11	Dissolved Solids	mg/L	500	2000	498 - 1556	980- 2690	184	2320
12	Suspended Solids	mg/L	*	*	-	-	-	< 1
13	Alkalinity as $CaCO_3$	mg/L	200	600	36 - 270	0 - 276	24	475
14	Hardness as $CaCO_3$	mg/L	300	600	350- 384	770-1980	116	755
15	Calcium as Ca	mg/L	75	200	72 - 92	164 - 552	30	166
16	Magnesium as Mg	mg/L	30	100	37 - 41	86 - 199	10	82
17	Chlorides as Cl	mg/L	250	1000	10 -35	62 - 87	10	406
18	Sulphate as SO_4	mg/L	200	400	42 - 225	309-1131	98	403

19	Nitrate as NO_3	mg/L	45	100	0.0658	-	-	NIL
20	Fluoride as F	mg/L	1	1.5	1.4	1.8- 2.2	0.5	1.6
21	Iron as Fe	mg/L	0.3	1	0.13- 0.23	0.1- 1.5	BDL	BDL
22	Copper as Cu	mg/L	0.05	1.5	-	-	-	0.014
23	Zinc as Zn	mg/L	5	15	-	-	-	0.29
24	Manganese as Mn	mg/L	0.1	0.3	0.06 - 0.24	-	BDL	BDL
25	Aluminium as Al	mg/L	0.03	0.2	-	-	-	BDL
26	Boron	mg/L	1	5	-	-	-	BDL
27	Oil & Grease	mg/L	0.01	0.03	-	-	-	NIL
28	N. Hexane extract	mg/L	*	*	-	-	-	NIL
29	Phenolic compounds	mg/L	0.001	0.002	-	-	-	NIL
30	Cyanide & its compound as CN	mg/L	0.05	NR	-	-	-	NIL
31	Free CO_2	mg/L	*	*	-	-	-	
32	Free Ammonia	mg/L	*	*	-	-	-	NIL
33	Free Chlorine as Cl_2	mg/L	0.2	--	-	-	-	NIL
34	Coliforms	MPN/100 ml	--	--	-	-	-	NIL
35	Cadmium & its compounds as Cd	mg/L	0.01	NR	-	-	-	0.05
36	Lead & its compounds as Pb	mg/L	0.05	NR	-	-	-	BDL
37	Chromium & its compounds as Cr	mg/L	0.05	NR	-	-	BDL	ABSENT
38	Selenium as Se	mg/L	0.01	NR	-	-	-	NIL
39	Arsenic & its compounds as As	mg/L	0.05	NR	-	-	-	-
40	Mercury as Hg	mg/L	0.001	NR	-	-	-	-
41	Pesticides	mg/L	ABSENT	0.001	-	-	-	-
42	Polynuclear Aromatic Hydrocarbon PAH		--	--	-	-	-	-
43	Water Depth	M	--	--	-	-	-	-
44	Water Column	M	-	--	-	-	-	-

NR : No Relaxation * : No specific limit prescribed CL : Colourless
UO : Unobjectionable AG : Agreeable BDL : Below detectable level

Situations are likely to be i) availability of sufficient mine water & a water treatment plant is possible with fluoride concentration up to 1.5 mg/L and absence of other toxic matter**.** ii**)** Water contains higher concentrations of fluoride and/or arsenic or other materials and where water is to be treated for only drinking water while untreated mine pit water is suitable for other uses. Probable approaches for these situations are given below

Alternative 1-Conventional treatment of water

1. Population /consumers: 1000 souls

2.	Per capita per day supply	@ 55 litres
2.	Water requirement/d @ 55 LPCD.	55 m^3/d
3.	Lime requirement for pH correction	10 – 25 mg/L*
4.	Alum dose in absence of fluoride	15 – 20 mg/L
5.	Additional alum dose for each mg F, mg/L in water	150-200 mg/L *
6.	Rapid mix to ensure marginal removal of F	2 minutes
7.	Flocculation time	8-10 minutes
8.	Settling time	150 minutes
9.	Surface overflow rate	4 m^3/m^2/hr
10.	Filtration rate	5 m/hr

* To be determined at site

Flow diagramme for conventional treatment for removal of suspended solids, correction of pH, minor reduction in hardness of acid mine water is shown in Figure 2. If fluoride removal is desired during conventional treatment then higher doses of alum and lime will be required.

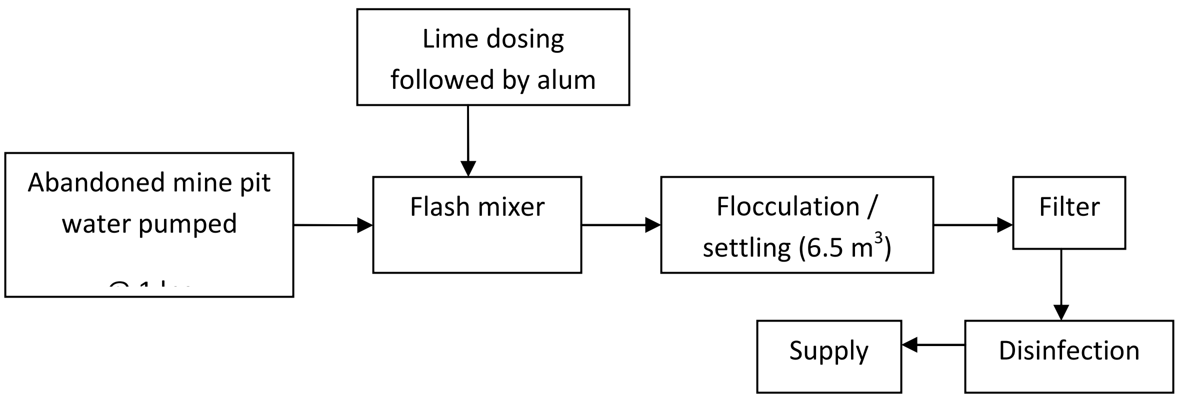


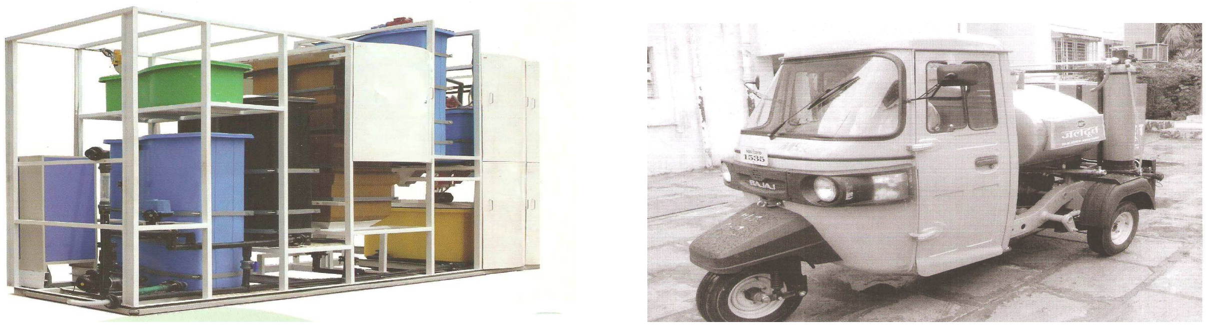
Figure 2: Conventional treatment flow diagram

It may be mentioned that stored water will have low turbidity. Nevertheless conventional chemical treatment is suggested because i) lime addition raises pH up to 8.5 - 8.9. Rise in pH favour hydrolysis of aluminium ions & formation of hydroxides of other metallic ions in mine water which will later be adsorbed on aluminium hydroxide flocs during flocculation, ii) additional flash mixing will ensure floc formation and adsorption of fluoride ions by polymeric species of alumino-hydroxo complexes. $Al(OH)_3$ will also reduce colloidal arsenic, if present.

A water treatment plant to treat goaf water @ 1.5 MLD was provided & constructed at Nandan in Kanhan coal field of WCL. It included cascade aeration for removal of iron (from FeS pyrite oxidation) in addition to the above flow diagram. Provision for lime-soda treatment for hardness reduction also was made. However, softening was not economical.

Alternative 2- Package plants & special treatment for fluoride removal

Package water treatment plants with conventional treatment are now available. A typical is shown in Figure 3(a). Most of unit operations for water treatment can be performed in such plants. Various containers in such a unit can be oriented, adjusted to the desired sequence of operation. It can have a computerized control panel also with automatic dozers, timers etc. Several firms make such modular units and are commercially available. Such units can be mounted over a vehicle shown in Figure 3(b). Vehicle mounted unit will treat mine pit water and transport it to the consumers.



(a) (b)

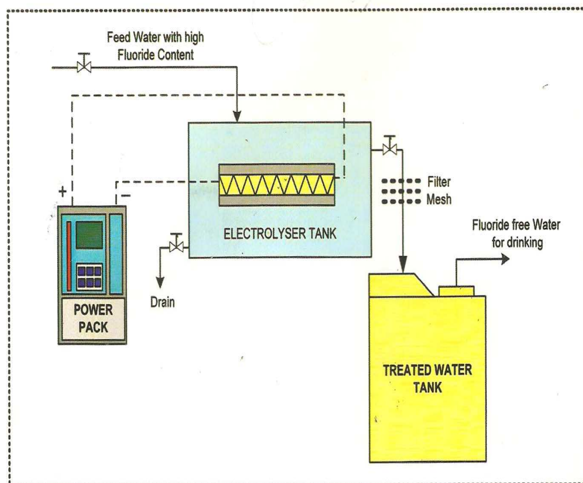
Figure 3 - A Package Plant

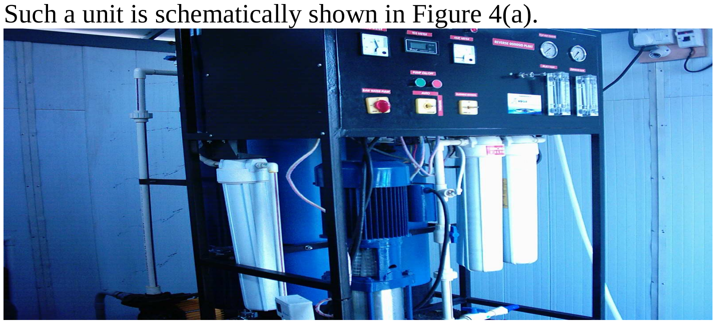
Such units work without electricity. They can reach from place to place. It can mount UF/RO membranes, pressure filter, softeners. Such a unit comprises of a centrifugal pump (1HP) coupled to shaft drive of the three wheeler automobile with chain drive. It will also have a 500 L stainless steel (SS) tank. Such mounted units are commercially available.

Special treatment like for fluoride removal units exclusively for domestic consumption are viable. Such units have been installed in number of fluoride-afflicted villages in Chandrapur, Warora and Yavatmal districts in Maharashtra.

Fluoride removal

Fluoride is removed during electrolysis using a sacrificial aluminum anode which releases aluminum ions during electrolysis. Aluminium ions in turn hydrolyse and form polymeric species known as alumino hydroxo complexes which adsorb fluoride. Such a unit is schematically shown in Figure 4(a).





(a) (b)

Figure 4(a) - Fluoride removal by electrochemical method
(b) – R.O. Plant

Reverse osmosis (R.O.) process can be used for high TDS water. Such units have been installed in fluoride affected villages in the above mentioned districts. A photograph of R.O. unit is shown in Figure 4(b).

Arsenic removal

Arsenic can be removed during reverse osmosis(R O.). Colloidal arsenic can probably removed by electro chemical method. Detailed studies are in progress. Aluminum hydroxide form during electrolysis will adsorb colloidal arsenic. If mine-pit water is highly acidic then alkalinity of water will have to be increased to enable aluminum hydroxide formation. Lime can be used to increase alkalinity. In case arsenic is organically bound then organic matter will have to be oxidized and oxidation by chlorine (bleaching powder, hypochlorite) is proposed

Conclusions

Situation existing in coal mining area can be summarized as under.

1) Mine pit water is away from residential colonies or habitations
2) It will be uneconomical to lay pipelines to transmit water by conventional distribution system to villages
3) Power is always available in active mining area.
4) Road network also is available with in mine.
5) Package water treatment plant utilizing both conventional and modern methods are available e.g. reverse osmosis (R.O.), ultra-filtration, or electro chemical units etc depending on the water quality
6) Centrally treated water can be transported by tankers to scarcity areas.

Following approach to utilize mine water is suggested

- Survey and collect information on mine pit water quantity, drinking water requirement and villages to be covered
- Collect representative samples and analyze them particularly for fluoride, arsenic, and heavy metals.

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