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Recovery of Alum Coagulant from Water Treatment Plant Sludge: A Greener Approach for Water Purification

Smita Joshi [1], Kriti Shrivastava [2]
Chemistry Department, Sarojini Naidu Govt. Girls P.G. College, Shivaji Nagar [1,2]

Abstract

The present work is based on Alum Recovery from the sludge obtained from Shyamala Water Treatment Plant by Acidic and Alkaline methods. In the acidic and alkaline method, the maximum recovery of alum coagulant is found to be 84.18% and 76.98% respectively. The recovered alum is as efficient as commercial alum and can be used again as coagulant for Water Treatment. This recovery can solve the vast problem of WTP (Water Treatment Plant) sludge management together with the problem of water pollution associated with disposal of alum sludge in the water body. In this way, this work tries to enlighten a greener approach for water purification which seeks to reduce and prevent the production of pollutant (WTP sludge) at its source.

Keywords

Alum Sludge, Water Treatment Plant, Acidic Method, Alkaline Method, Alum Recovery.

1. Introduction

One of the most important crises of the 21st century is the availability of clean drinking water, a resource important for our survival and growth. Most of the fresh water bodies all over the world are getting polluted due to unplanned urbanization, industrialization and anthropogenic activities [Singh et.al. 2002][7]. The surface water sources serve as the best sinks for the discharge of domestic as well as industrial waste. The unscientific disposal of waste has caused immense problems not only to human beings but also to aquatic environment world [Dhage et.al. 2003][4].

In Bhopal, the capital city of M.P. with more than 1.5 million residents, have a water consumption rate of 72 litre per capita per day including non-residential use [www.indiawaterportal.org][9]. Water supply to Bhopal is largely dependent on the Kolar Dam and the Upper Lake. Both are rain-fed sources and are thus vulnerable to seasonal fluctuations.
The Kolar reservoir, located about 31 km from Bhopal, supplies water to about 65% of the city's population. The Upper Lake is an artificial rain-fed lake right in the heart of the city and acts a major source of water supply to the city. Raw water is extracted from the lake at seven different points from where it is treated and pumped to the distribution network. Apart from supply to the distribution network direct supply is also provided to bulk consumers like BHEL (Bharat Heavy Electrical Limited), MES (Military Engineering Services), Central Railways and Straw products. [Water Demand Management Strategies and Implementation Plan For Bhopal, UN-HABITAT (2006)][8].

TABLE 1:
Water Supply Details Of Bhopal City
[Source: Water Demand Management Strategies and Implementation Plan for Bhopal, (2006)]

S.No.	Water Supply Source & Water Treatment Plants (WTP)	Water Supply Capacity (MGD)
A.	KOLAR DAM	
1.)	Kolar WTP	32.5
B.	UPPER LAKE	
1.)	Shyamala-1 WTP*	4.18
2.)	Shyamala-2 WTP	2.02
3.)	Badal Mahal WTP	1.00
4.)	Idgah WTP	3.46
5.)	Areara WTP	5.00
6.)	Pulpukhta WTP	1.90
7.)	Hirda Ram Nagar WTP	1.07
C.	GROUND WATER (TUBE WELLS)	5.0

(* Site of Sampling and Study)

Alum is generally used in water treatment plants (WTPs) as a coagulant. Alum reacts with water forming an insoluble aluminum hydroxide flock which removes the fine suspended and colloidal impurities. Daily a large quantity of fresh alum is required in Water Treatment Plants where large

amount of sludge generated as waste water which cannot be discharged in surface water without proper treatment.

This sludge consists near about 40-50% of unused alum. If alum coagulant can be recovered efficiently from WTP Sludge, then it will solve the problems of sludge disposal, water pollution and daily huge requirement of fresh alum. In this way, it can provide a greener approach for water purification in which according to the principals of Green Chemistry, which seeks to reduce and prevent the pollution at the source (Wikipedia, the Encyclopedia)[10].

2. Methodology

I. Sludge samples are collected from Shyamala Water Treatment plant and their physico-chemical characteristics are determined as per the methods prescribed in APHA (1989)[1]and NEERI (1986)[6]. Then sludge samples are subjected to alum recovery process.

II. Alkaline Extraction Process

Since Aluminium Oxide is amphoteric in nature, when NaOH is added to the WTR, Al^{3+} is returned to the solution in the form of Sodium Aluminates.

$$\underset{\text{Solid WTP Sludge}}{Al(OH)_3 + NaOH} \longrightarrow \underset{\text{Recovered Alum}}{NaAlO_2 + 2H_2O}$$

In this method NaOH is added to WTR (Water treatment residuals) in different ratio (1:1, 1:2, 1:3, 1:4, 1:5) to increase pH to a level such that the Al^{3+} ion returned to the solution in the form of sodium aluminate. In this reaction some phosphate ions are also returned to the solution, therefore $CaCl_2$ is added to precipitate phosphate in the form of Calcium Phosphate. Then alum is separated from it by filtration. The filtrate undergo concentration and crystallization which ultimately gives the recovered alum crystals (Bhole , 2001)[3].

III. Acidic Extraction Process

When WTR is sufficiently acidified with sulfuric acid, insoluble $Al(OH)_3$ is dissolved in the form of dilute liquid alum.

$$\underset{\text{Solid WTP Sludge}}{2Al(OH)_3.3H_2O + 3H_2SO_4 + 2H_2O} \longrightarrow \underset{\text{Recovered Alum}}{Al_2(SO_4)_3.14H_2O}$$

The thickened sludge from the clarifier is pumped into the acidification tank in which rapid mixing is provided and the reaction occurs. Then the acidified WTR is placed in gravity sedimentation tank from where the supernatant liquid containing dissolved aluminium is recovered for reuse as a coagulant while the solid from the underflow of separator are sent to the dewatering unit. The solids from the dewatering unit can be disposed of in a sanitary landfill and the liquid from the dewatering unit can be reused as a coagulant (P. George Fulton, 1976) [5].

IV. Al^{3+} Ion Concentration Determination

The trivalent aluminium concentration in the sludge is determined by Erichrome Cyanine R Method. The apparatus used is Spectrophotometer: EI model 1371 with wavelength 535nm.

3. Result and Discussion

Present study reveals that purification of water is a daily need based task, because only in the Bhopal the requirement of potable water supply is 90 MGD. Several water treatment plants are working simultaneously in Bhopal alone and they require a huge quantity of fresh alum daily. In addition to this, after water treatment alum sludge cannot be discharged into surface water or landfill directly. It requires proper treatment before its disposal to either place.

These Water Treatment Plants are basically industries for production of potable water. Large amount of Alum sludge is generated after water treatment in clarri-flocculator unit. So by recovery and recycling of alum, we can reduce the need of more fresh alum and hence can reduce the overall operation cost.

During rainy season sludge samples are taken. By acidic method, the maximum alum recovery is 84.18% at the initial pH value of 9.0. By alkaline method, maximum alum recovery is 76.98% at feed pH 12.0 with optimum value of 75 mg/l of $CaCl_2$ dose added for precipitation of PO_4^{3-} ion as $Ca_3(PO_4)_3$.

Recovery Of Alum By Acidic Method
Shyamala Water Treatment Plant, Bhopal
(During Rainy Season)

Table 2: Recovery of Al^{3+} in percentage at different pH values

S.N.	Parameters	Water Treatment Plant			
		Sample A	Sample B	Sample C	Sample D
1.	Initial pH	8.0	7.9	9.0	7.8
2.	Sludge Volume (ml)	100	100	100	100
3.	S.S. Conc (mg/L)	330	270	250	300
4.	Total Al^{3+} in Sludge	39.50	38.90	42.92	38.0
5.	pH after addition of 1N H_2SO_4	3.90	2.95	**2.67**	5.95
6.	1N H_2SO_4 added (ml)	4.38	4.32	4.80	7.33
7.	Al^{3+} recovered (mg)	32.82	32.42	36.10	27.2
8.	% age Recovery	83.10	83.35	**84.18**	71.57

Maximum recovery of Alum is obtained at pH 2.67. On further increase in pH value, the recovery of alum would be decreased.

Recovery Of Alum By Alkaline Method Shyamala Water Treatment Plant, Bhopal (During Rainy Season)
Recovery of Al^{3+} in percentage for Feed pH = 12.0
SS Concentration – 250 mg/L
Sludge Volume Taken – 100.0 ml
NaOH Concentration – 500.0 ml/L
Initial pH – 9.0
Total Al^{3+} Concentration- 45.76 mg/L
Feed pH – 12.0

Table 3:

S.No.	**Sludge Sample + NaOH Added**	**Recovery of Al^{3+} in mg/L**			
		$CaCl_2$ added in mg/L			
		25	**50**	**75**	**100**
1.	1:1	39.20	44.82	45.85	43.29
2.	1:2	42.14	45.41	53.52	51.70
3.	1:3	47.87	50.97	59.52	55.10
4.	1:4	48.42	55.79	68.92	60.75
5.	**1:5**	55.72	59.52	**76.98**	61.82

At feed pH=12.0, the maximum recovery of alum is obtained when NaOH is added 5 times to the sludge volume.

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