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Probability of Aluminium Toxicity in Water Treatment Plant Itanagar: A Case Study

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***Abstract*— Itanagar Water Treatment Plant is one of the oldest water treatment plants serving the community of this region. It supplies water to most of the part of Itanagar. Senkhi River has been chosen as the source of water supply to Itanagar Township. The river has a minimum discharge of 8857 MLD which is sufficient for the water requirements of Itanagar Township even beyond the year 2021. The quality of river water satisfies the requirements predicted by Public Health Engineering department. The treatment plant has been using Alum as a coagulant in treatment process for the past 12 years. The backwashed water along with the settled sludge from the plant is released into nearby locality which carries a significant amount of suspended matter. Therefore, layer of sludge is supposed to be deposited on the meeting point of backwashed water and the river. Due to release of such sludge and backwashed water, the soil at the disposal site and sediment of the river could get affected by aluminium toxicity in near future. Recent studies showed that alum may produce aluminium toxicity at certain situation, especially at lower pH. Due to this or some other reasons, alum is being replaced by other chemicals. Experimentation work including both field and laboratory tests were conducted to determine the aluminium concentration in the soil and water at the place where the backwash water and sludge from Itanagar Water Treatment Plant are discharged off.**

Keywords—Absorbance, Alum, Backwash Water, Coagulant, **T**urbidity.

I. INTRODUCTION

Itanagar Water Treatment Plant is one of the oldest Water Treatment Plants serving the community of this region. It supplies water to most of the part of Itanagar. Senkhi River has been chosen as the source of water supply to Itanagar Township. The river has a minimum discharge of 8857 MLD which is sufficient for the water requirements of Itanagar Township even beyond the year 2021. The quality of river water satisfies the requirements predicted by PHED department. Treated water from the plant is distributed to the areas, such as Chandanagar, Police colony, Degree college, Senkhi park area, Civil Secretariat complex, Indira Gandhi park, C1 sector, C2 sector, Nyokum Lapang area, Adi Basti area, H sector, C sector, MOWB-II area, Upper ESS, G sector, F & G, Vivek vihar, Ganga market, F sector, VIP road, A sector, B sector, P sector, Raj Bhawan complex, Senkhi view, etc. Further other areas have been brought under new connection, *e.g.*, Nyokum Lapang, Central School, Forest Corporation, Police Battalion HQ, Office of Economics & Statistics, Greater part of Chimpu, Gohpur Tinali areas, etc.

The treatment process of this plant includes sedimentation, filtration and disinfection. Alum is used as a coagulant during coagulation process to settle down suspended solids and the settled sludge is removed from clarifier at periodic intervals. Aluminium (Al) is a component of alum and it could be toxic to environment at acidic pH [1]. The treatment plant has been using Alum as a coagulant in treatment process for past 10 years. The backwashed water along with the settled sludge from the plant is released into nearby locality which carries a significant amount of suspended matter. Therefore, a layer of sludge got deposited on the meeting point of backwashed water and the river. Due to release of such sludge and backwashed water, the soil at the disposal site and sediment of the river could get affected by Al toxicity in near future. Also, Al present in sludge deposit could leach into the nearby soil and thereby affects the plant growth. The high concentration of Al could have a direct impact on flora and fauna and an indirect effect on human beings. Some of the recent study showed that Al under acidic pH could affect the growth of flora and fauna [2, 3]. Similarly, prolong exposure to

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Al causes neurological disorder [4], Alzheimer's disease [5], Parkinson's disease, osteomalacia and anaemia [6] in human.

Almost all the Water treatment plants uses alum as the coagulant, thus generate large amounts of Al rich alum residuals that are discharged directly into surface water. Alum may produce aluminium toxicity at certain situation, especially at lower pH. Due to this or some other reasons, alum is being replaced by other chemical as coagulant. For example, the water treatment plant at Bhandup Complex, Mumbai, that supplies water to most of the part of Mumbai, was been using alum as a coagulant in the water treatment process for the last 27 years but now the plant is s no more using it. Thus, a study is required to examine the suitability of alum as coagulant along with its impact on environment, for all water treatment plant. The objective of the present study was to estimate the toxic effect of alum on the soil and water at the place where sludge and backwash water from Itanagar Water Treatment Plant are discharged off. The results revealed the suitability of alum as a coagulant at the Itanagar treatment plant or to find for other chemical.

II. Aluminium Toxicity

Aluminium enters the atmosphere as a major constituent of atmospheric particulates originating from natural soil erosion, mining or agricultural activities, volcanic eruptions, or coal combustion. Atmospheric Al concentrations show widespread temporal and spatial variations. Airborne Al levels range from 0.0005 $\mu g/m^3$ over Antarctica to more than 1 $\mu g/m^3$ in industrialized areas [7]. Al levels in drinking-water vary according to the levels found in the water source and whether Al coagulants are used during water treatment.

Aluminium is present in foods naturally or from the use of Al-containing food additives. The use of Al cookware, utensils, and wrappings can increase the amount of Al in food; however, the magnitude of this increase is generally not of practical importance. Foods naturally high in Al include potatoes, spinach, and tea. Processed dairy products, flour, and infant formula may be high in Al if they contain Al-based food additives [7]. Adult dietary intakes of Al (mg/day) have been reported in several countries: Australia (1.9–2.4), Finland (6.7), Germany (8–11), Japan (4.5), Netherlands (3.1), Sweden (13), Switzerland (4.4), United Kingdom (3.9), and USA (7.1–8.2). Intake of children 5–8 years old was 0.8 mg/day in Germany and 6.5 mg/day in the USA. Infant intakes of Al in Canada, the United Kingdom, and the USA ranged from 0.03 to 0.7 mg/day [7].

Al is not regarded as an essential nutrient, but low concentrations can sometimes increase plant growth or induce other desirable effects. Al toxicity is an important growth-limiting factor for plants in acid soils below pH 5.0 but can occur at pH levels as high as 5.5 in mine spoils. Generally, Al interferes with cell division in root tips and lateral roots, increases cell wall rigidity by cross linking pectin, reduces DNA replication by increasing the rigidity of the DNA double helix, fixes phosphorous in less available forms in soils and on root surfaces, decreases root respiration, interferes with enzyme activity governing sugar phosphorylation and the deposition of cell wall polysaccharides, and the uptake, transport, and also use of several essential nutrients (Ca, Mg, K, P and Fe). Excess Al even induces iron (Fe) deficiency symptoms in rice and wheat.

III. Alum as a Coagulant

This is the most common and universal coagulant used in water works. Its chemical composition is $Al_2(SO_4)_3$ 18 H_2O. It requires the presence of alkalinity in water to form the flocs. Most water has bicarbonate alkalinity naturally in them. When dissolved in water, aluminium sulphate tends to hydrolyze into aluminium hydroxide, as is evident from the following reaction:

$$Al_2(SO_4)_3 18H_2O + 3Ca(HCO_3)_2 = 2Al(OH)_3 + 3CaSO_4 + 18H_2O + 6CO_2 \quad (1)$$

The aluminum hydroxide formed above is insoluble in water and, therefore, forms flocs. If natural alkalinity in water is insufficient to react with alum, lime is also added to water. The lime (CaO) unites with water to form calcium hydroxide $Ca(OH)_2$ or hydrated lime which reacts with alum as follows:

$$Al_2(SO_4)_3 18H_2O + 3Ca(OH)_2 = 2Al(OH)_3 + 3CaSO_4 + 18H_2O \quad (2)$$

Sometimes sodium carbonate, known as soda ash, is added to form alkalinity. The resulting reaction is:

$$Al_2(SO_4)_3 18H_2O + 3Na_2CO_2 = 2Al(OH)_2 + 3Na_2SO_4 + 3CO_2 + 18H_2O \quad (3)$$

Coagulation & Flocculation in Water Treatment

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Coagulation is the chemical technique for destabilization of charged colloidal particles. Flocculation is the slow mixing technique which promotes the agglomeration of the stabilized particles. But for all practical purpose of addition of chemicals (coagulants) and mixing (flocculation) is usually referred as coagulation. Its efficiency depends on the following factors:

- Dosages of coagulant
- Feeding
- Mixing
- pH value
- Velocity

Coagulation Practice

Aluminium sulphate, the most commonly used coagulant in water purification, is most effective between pH ranges of 5.0 to 7.5, ferric chloride is effective down to pH 4.5, and ferrous sulphate is effective only above pH 9.5. Although less expensive than alum, these coagulant can cause color problems if the precipitate is not removed completely. It is sometimes advantageous to use synthetic polymers in addition to alum. These polymers bind small flocs together to make larger masses for faster settling. Depending upon the turbidity and nature of water alum dosage may range from 5 to 50 mg/L. At the low turbidity and high dosage, aluminium hydroxide is certain to form so that predominant turbidity-removal mechanism is sweep coagulation.

At high turbidity and lower dosage, adsorption and charge neutralization mechanism will be predominant, although inter-particle bonding probably plays a significant role. Ionic layer compression would not be significant at these concentrations. With regards to coagulation, surface water can be grouped into the four general categories describe below:

Group 1 (High turbidity-low alkalinity): With relatively small dosages of coagulant, water of this type should be easily coagulated by adsorption and charged neutralization. Depression of pH makes this method more effective, since the aquometallic ions are more effective at lower pH values. However, care should be taken to prevent excessively low pH.

Group 2 (High turbidity-high alkalinity): The pH will be relatively unaffected by coagulant addition. Because of the high alkalinity, adsorption and charge neutralization will be less effective than in water of low alkalinity. Higher coagulant dosage should be used to ensure sweep coagulation.

Group 3 (Low turbidity-high alkalinity): The small number of colloids make coagulation difficult, even if the particle charge has been neutralized. The principal coagulation mechanism is sweep coagulation with moderate coagulant dosage. Addition of some turbidity may decrease the amount of coagulant needed.

Group 4 (Low turbidity-low alkalinity): Again, the small number of colloids makes coagulation difficult, and low alkalinity prevents effective aluminium hydroxide formation. Additional turbidity can be added to convert this water to that of group-1 or additional alkalinity can be added to convert it to a group 3 type. It may be advantageous to add both turbidity and alkalinity.

IV. EXPERIMENTAL SECTIONS

(a) Field Work

Samples including soil and water were taken from various points at the suitable intervals along the drain (that discharge off the backwash water along with the sludge) and the river stream. S1, S2, etc. denote the position from where soil samples were taken for testing purpose. Similarly, W1, W2, etc. denote the position from where water samples were taken for testing for aluminium concentration.

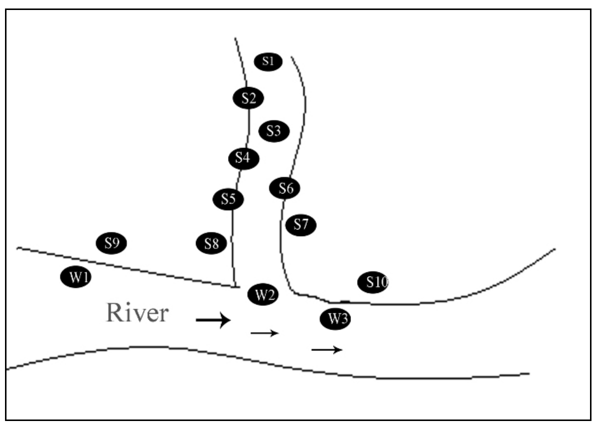

Fig. 1 Location of Sampling Points

(b) Laboratory Work

Following tests were carried out in the laboratory.

Determination of pH of the Samples

The pH of the liquid samples was determined directly using pH meter. The pH of soil samples were determined by Standard method. Soil samples was mixed with distilled water in a ratio 1:2 in 100 ml beaker and stirred it with glass rod intermittently for 30 minutes and filtered it through sand paper. Then the pH was determined using pH meter as in the case of liquid sample.

In general for mineral soils with medium to high Al concentration:

- The pH below 5.0, soluble Al is almost certainly a problem.
- The pH between 5.0 and 5.5, soluble Al may be a problem.
- The pH between 5.5 and 6.0, soluble Al not likely to be a problem.
- The pH above 6.0, soluble Alis almost certainly not a problem.

Determination of Al Concentration

The testing for Al concentration in soil and liquid samples taken from different locations were done in the Environmental Engineering Laboratory of Indian Institute of Technology, Guwahati. The inorganic soil samples were first converted into organic form by Standard Method [8] and then subjected to AAS (Atomic Absorption Spectrometry) for Al concentration determination.

In their elemental form, metals will absorb ultraviolet light when they are excited by heat. Each metal has a characteristic wavelength that will be absorbed. The AAS instrument looks for a particular metal by focusing a beam of UV light at a specific wavelength through a flame and into a detector. The sample of interest is aspirated into the flame.

If that metal is present in the sample, it will absorb some of the light, thus reducing its intensity. The instrument measures the change in intensity. A computer data system converts the change in intensity into an absorbance.

Then, samples were tested and measured against this curve. As concentration goes up, absorbance progressed. The calibration curve of various concentrations on the AAS was drawn by observing the absorbance (Table 1). In laboratory, the curve was drawn by computer data system as shown in Fig 2.

TABLE 1. Absorbance for Different Al Concentration

Concentration (mg/L)	Absorbance
20	0.0703
40	0.1221
80	0.2332
100	0.2449

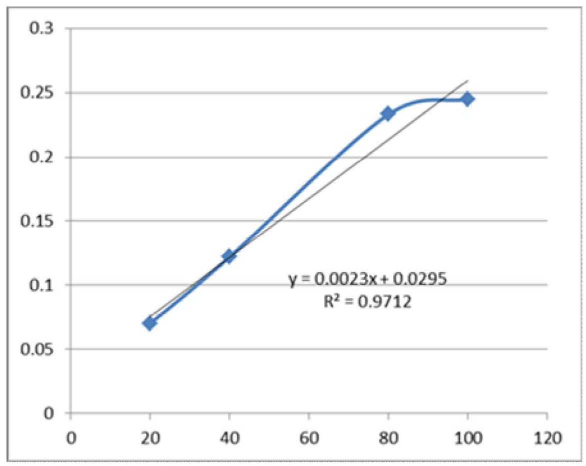

Fig. 2 Calibration Curve between Al Concentration and Absorbance

V. RESULTS AND DISCUSSION

The experimental results are presented in Table 2. The results show that the Al concentration of the soil and water samples taken around the sludge deposit site of Itanagar water treatment plant is within permissible limit. Further the pH values of those samples are around neutral (ranges from 6.7 to 7.4). Hence the chance of Al toxicity at lower pH (higher acidity) is not possible at that location. However, care should be taken that no industrial effluents of acidic nature meet the downstream side. Otherwise further monitoring would be necessary.

Table 2 pH Value & Al Concentration of Different Soil and Water Samples

Samples		pH	Al Concentration
Soil samples			(g/kg)
Along the drain	S1	7.4	50.39
	S2	7.2	41.55
	S3	7.4	57.22
	S4	6.6	64.25
	S5	6.8	66.29
	S6	6.7	71.06
	S7	7.2	65.39

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	S8	7.5	48.84
Upstream river bank	S9	6.7	43.06
Downstream river bank	S10	7.1	53.59
Water sample			(mg/L)
Upstream	W1	7.4	40.63
Junction point	W2	6.8	45.02
Downstream	W3	7.2	51.34

V. CONCLUSION

The following conclusions are drawn out from the results while conducting the experiment on aluminum toxicity:

- Water treatment plants generate large amounts of Al rich alum residuals that are discharged directly into surface waters.
- Concerns of residual disposal into surface water have been associated with elevated aluminum concentrations.
- Aluminum in alum residual is soluble in water and insoluble in alcohol.
- Exposure to aluminum is usually not harmful, but exposure to high levels can cause serious health problems. Large parts of both the aquatic and terrestrial ecosystems are affected.
- The pH of the water and soil sample is alkaline in nature.
- At present the Al concentration of the soil and water samples taken around the sludge deposit site of Itanagar water treatment plant is within permissible limit.
- The pH values of those samples are around neutral (ranges from 6.7 to 7.4). Hence the chance of Al toxicity at lower pH (higher acidity) is not possible at that location.
- Care should be taken in future that no industrial effluents of acidic nature should meet the river in downstream side. Otherwise further monitoring would be necessary.

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