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Study of methodology for removal of Arsenic contamination from public water supply projects-West Bengal perspective.

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Abstract:- Water supply projects utilize surface water, sub-surface water and ground water as sources. The most economical alternative is to use ground water as source, because it will not require construction of water treatment plant for surface or sub-surface based water supply schemes, which involves high capital cost. However for areas which are far away from the river, it is not viable to utilize river water for source for such areas ground water is the only preferable source to feed the water supply scheme. If the area receives substantial rainfall throughout the year the ground water reserve in the aquifer is easily replenished and hence abstraction of ground water through production tubewell shall be a sustainable approach to provide drinking water supply to the population. As ground water is generally abstracted from confined aquifer, the water quality of ground water is free bacteriological contamination. However the main evil in ground water is chemical contamination. One of the most significant chemical contaminant in ground water is Arsenic, which is a cumulative poison in human system. Prolonged intake of arsenic laden water in relatively higher concentration, results in manifestation of toxic effects of arsenic in human body, various health related problems develop due to arsenic poisoning which is broadly termed as “Arsenicosis”. Arsenic contamination in ground water is observed across the globe, the problem is very wide spread in West Bengal. In this paper a time tested methodology for effective removal of arsenic from drinking water is discussed. The methodology incorporates oxidation followed by coagulant assisted precipitation, and finally applying adsorption technique using polishing agent for removal of residual arsenic so that the treated water has arsenic below detectable limit. The method is easily implemented at the field and the operation and maintenance of the plant is less. The process has been indigenously developed for field application for public water supply schemes and provides potable water to the population in reliable quality.

Keyword:- Arsenic removal, ground water, arsenic contamination, water quality.

(i) Introduction:- Arsenic contamination in ground water is observed widely across the globe. The problem is prevalent in India and is very significantly observed in the state of West Bengal. As per assessment arsenic contamination is most prominent in the 8 districts of West Bengal including North 24 Parganas, South 24 Parganas, Hooghly (part), Purba Burdwan (part), Nadia, Murshidabad, Maldah and only few

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scattered villages of Howrah (refer Fig no.1). In these 8 districts about 84 blocks, 3319 villages and 8153 habitations are affected from arsenic infestation in ground water and about 16.5 million rural population of West Bengal are at risk due to this arsenic contamination. All the 84 blocks are located by the bank of the river Hooghly and its adjoining areas. The analysis of ground water sample in this areas indicated higher arsenic concentration in ground water. The contamination is mostly observed at a depth of 20m-80m below G.L. prolonged ingestion of arsenic through food and drinking water causes accumulation in the human body, arsenic can be traced in hair, nail, urine and other body parts. Due to the toxic effect of arsenic lesions develop in the palms and the foot(refer fig no.2). Diarrhea and other abdominal problems may occur, in severe cases kidney may be affected and cancer may develop. If the problem is detected at an early stage and the patient is removed to a location where drinking water is free from arsenic contamination, the patient is found to improve in health, due to flushing out of accumulated arsenic from the system. It has been found that the effect of arsenic toxicity is manifested significantly in case of individuals suffering from malnutrition i.e. among the poor people. In the late 1980s water testing reports revealed higher concentration of arsenic in water beyond the tolerable limit of 0.05mg/l in shallow tubewells. Later arsenic in higher concentration was also observed in India Mark-II head fitted deep water pump type tubewell. Initially it was thought that stray cases of arsenic contamination was due to the activity of the farmers who spray fertilizers of arsenic based compounds to the crops, but later on realizing the huge extent of the problem it was concluded that detection of higher level of arsenic is possibly due to geological causes. So far the reason for extensive infestation of arsenic contamination is unknown. The question of delivery of arsenic free drinking water to the population was a very compelling question to the water supply Engineer of West Bengal. The issue was a big concern which led to the formation of arsenic Task force in 2005 by the Govt. of West Bengal a technical committee with the terms of reference to explore and give approval to such technologies for arsenic removal after appropriate evaluation and proper pilot study at the site. The Public Health Engineering Department, Govt. of West Bengal, has taken the most significant initiative in the aspect of provision of Arsenic free drinking water to the population of the state. The initiative has involved construction of Mega piped water supply projects with Surface and Sub-Surface water, from the major rivers in West Bengal (mainly river Hooghly) for the areas which are located near the river bank and for the other areas where it is difficult to transport raw water of river due to relatively greater distance from the river, through sinking of big diameter deep tubewell to deeper aquifer free from arsenic and in areas where the aquifers are infested with arsenic contamination use

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of Arsenic-Cum-Iron removal plant has water to the been made to ensure Arsenic free drinking water to the population. A elaborate system of water testing laboratories both of PHED and NGO driven labs were established to ensure efficient testing of water samples across the state.

(ii) Removal technology:- Arsenic is a metalloid, it is found in ground water and usually exists as inorganic arsenic in both trivalent (As (III)) and Pentavalent (As(V)) species. As(III) has relatively higher level of toxicity in comparison with As(V). Various technologies are available for removal of Arsenic from ground water. The technologies are based on following principals:-

(a) Coagulation/co-precipitation,
(b) Adsorption,
(c) Sedimentation,
(d) Ion exchange,
(e) Membrane/Reverse Osmosis,
(f) Biological treatment,
(g) Nano technology based process etc.

All the above technologies have case specific advantages and disadvantages.

The removal of arsenic from water depends on the type of arsenic species present is water. As an example coagulation/co-precipitation method using iron or aluminum salts yield better result for Arsenic (V) species rather than arsenic (III). Thus to enhance the process of removal at first oxidation of the raw water is required so that all As(III) species is oxidized to As(V) and then the removal is done by coagulation/co-precipitation. The sedimentation process is adopted following coagulation/co-precipitation for effective removal of Arsenic species from solution. The mostly widely used Arsenic cum iron removal plant (AIRP) is based on the methodology of oxidation followed by co-precipitation through coagulation, flocculation, clarification and finally filtration (either through rapid sand filter or pressure filter) and then adsorption using activated alumina. The process finally yields water with arsenic within acceptable limit as per BIS guidelines. As per the current BIS code of practice IS-10500-2012 [1] with amendment, vide table 3 sl no. X, the acceptable limit for Arsenic is 0.01 mg/l and there is “no relaxation” to this quality standard. This method is capable of removing the arsenic and iron content from ground water so that water is fit for human consumption only with disinfection by chlorination. The process of coagulation is achieved with the addition of metal based coagulant such as Ferric chloride ($FeCl_3$), the coagulant hydrolyses in water forming positively charged Ferric Hydroxide ($Fe(OH)_3$). However the process to work effectively Arsenic must be oxidized to As(V) state.

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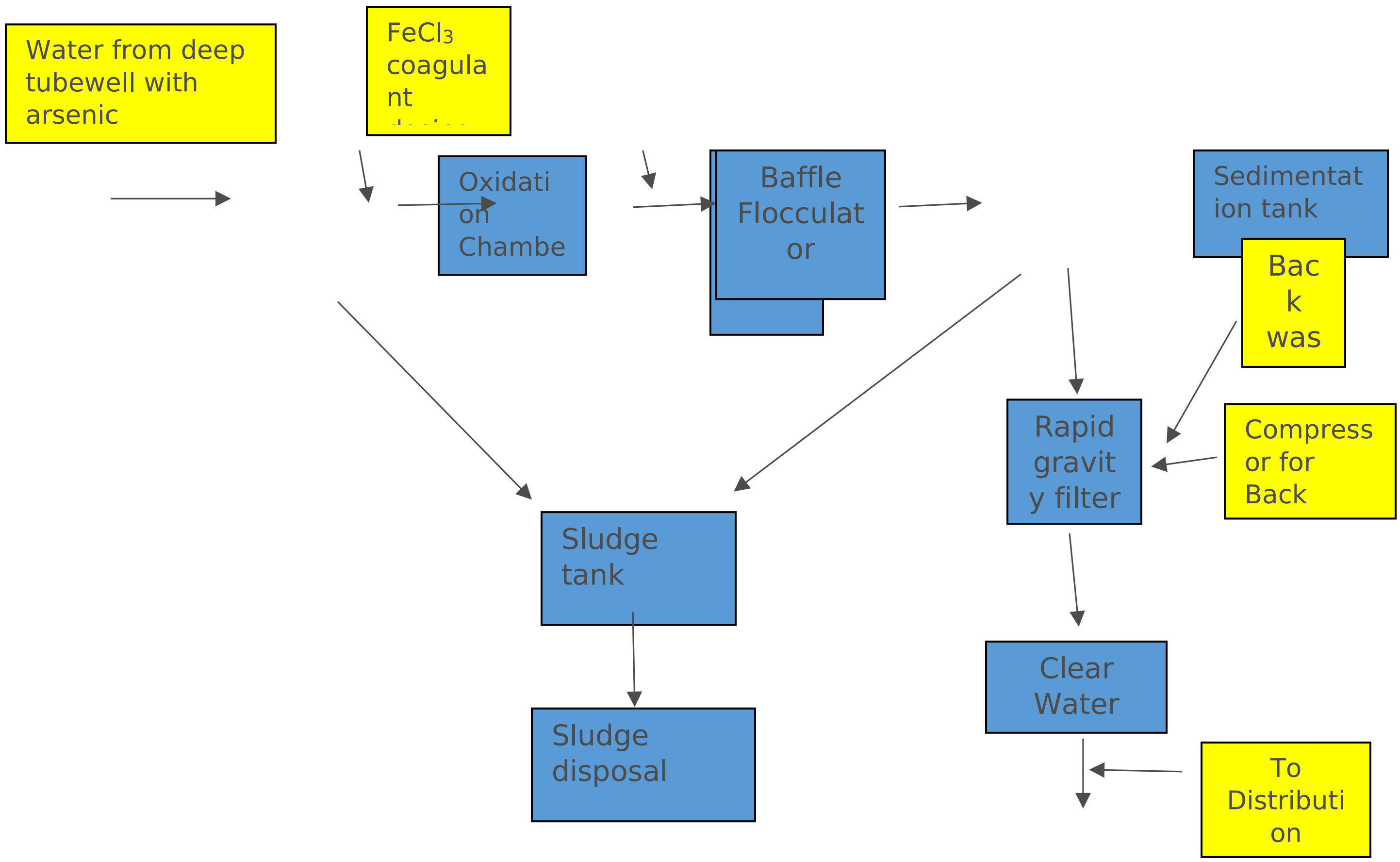
(iii) Process flow:- The process flow for Arsenic –Cum-Iron removal plant with oxidation, co-precipitation and polishing method is depicted below for clarity of understanding.



Effective performance of the above type of AIRP is much dependent on coagulation and sedimentation of the Arsenic present in the water. For ensuring removal of the arsenic species as As(V) the coagulant $FeCl_3$ is mixed at first violently in the mechanically operated flash mixer for uniform mixing. This operation is termed as rapid mixing. The water is then gently stirred and circulated in the baffles of the baffle flocculator to keep the colloidal particles in suspension and to promote collision between the colloidal particles so as to ensure effective formation of floc to assist in sedimentation. This type of AIRP may be economically constructed for ground water based piped water supply scheme with capacity varying from 30 CuM/hr to 180 CuM/hr. The AIRP can be fitted for rural piped water supply schemes with population varying from 15000 to 20000 souls. The structure is constructed with M30 grade R.C.C and Steel reinforcement providing adequate cover to the reinforcement a required vide provision of IS 456-2000 [2] and IS-3370 (part-2) 2009 [3] for water retaining structures. Flow in the different units of the plant is maintained through gravity. Proper assessment of the natural slope of the site is essential for laying out the plant. The oxidation chamber should be designed for 30 minutes detention period to ensure proper oxidation of As(III) to As(V) for proper functioning of the unit. As the process flow is based on gravity system least use of electro-mechanical instruments are done, the energy cost and the operation maintenance cost of the scheme is relatively less. Arsenic removal efficiency of the plant has been assessed between 92-95%. A significant difficulty associated with the plant is disposal of sludge generated at the sedimentation tank of the AIRP. The sludge has high concentration of Arsenic. The sludge cannot be disposed of by burying in the ground, as it will cause leaching of Arsenic in the shallow depth water table aquifer and shall further aggravate contamination in the locality. However as the concentration of arsenic in ground water is generally found in the range of 1mg/l to 0.05mg/l (however higher concentrations are also encountered) it takes considerable time to accumulate substantial thickness of sludge layer and hence sludge disposal is not required at frequent intervals. Researchers have established that sludge may be effectively disposed by mixing with clay for brick manufacturing or mixing with concrete in controlled ratio. Details of the process of sludge disposal is available elsewhere in literature [4].

(iv) Conclusion:- Supply of potable drinking water to the population in proper quality and adequate quantity is the mandate for a progressive society. Nature has posed a challenge to humanity in the form of arsenic toxicity in ground water which is a major impediment for providing wholesome drinking water to the population. This hazard can be combatted with three fold approach (a) using surface or Sub-surface water as source for water supply, (b) using ground water from deeper aquifers which is not contaminated with arsenic & (iii) using ground water source with Arsenic –cum –Iron removal plant. Where surface and sub-surface water from major rivers are available mega water supply project can be developed by construction of Water treatment Plant (WTP) at huge capital cost and recurring operation and maintenance cost. The cost of acquiring land for WTP is also substantially large which also adds to the capital cost. As an alternative ground water based water supply scheme is a preferable alternative. Thus Ground water based water supply scheme with exploitation of ground water in deeper aquifer and fitted with AIRP is a popular alternative. In areas where ground water in deeper aquifer is free from arsenic AIRP may be installed because with overexploitation of ground water leaching of arsenic may take place form shallow aquifer to deeper aquifer, and the arsenic free layer may develop contamination in near future. Among the various technology for removal of arsenic available the one with oxidation followed by co-precipitation and then activated alumina polishing unit with gravity flow model is the most economic and practical approach for arsenic removal for public water supply schemes, hence it is discussed in this

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paper and is suggested for adoption for arsenic removal in water supply schemes.

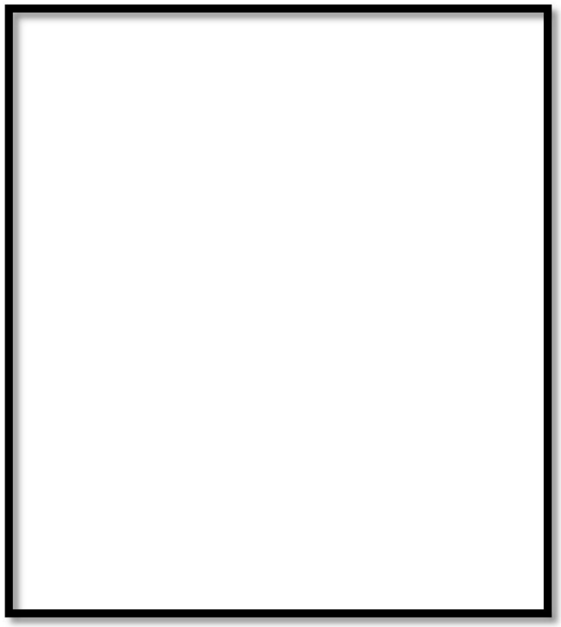

Fig 1. The map showing groundwater pollution by Arsenic, in the inter-fluvial region of the **Bhagirathi-Hoogli** and the **Jalangi-Ichamati** rivers lying mostly in the **eastern part of the Bhagirathi-Hoogli** river of West Bengal. The Arsenic contamination in ground water beyond **0.05 mg/l** has been found within the **shallow aquifer (20-80m below ground level) (obtained from official website of PHED WB).**

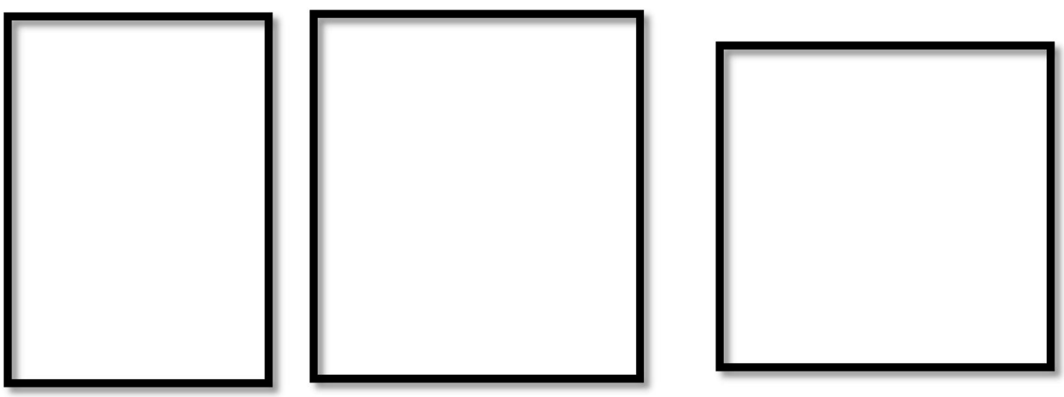

Fig 2. Showing the skin lesions developed in the palms and foot of Arsenic affected patient

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(v) References:-

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