PROJECT COMPLETION REPORT

DST File No. **DST/TM/WTI/2k16/95**

1. Project Title: **Decentralized water treatment for removal of arsenic, fluoride and mercury from drinking water**

2. Duration of Project: From 22/05/2017 To 15/12/2020

(Including extended period from 21/05/2020 to 15/12/2020)

3. Principal Investigator:

Name: **Prof. Robin Kumar Dutta**

Institute: **Tezpur University**

4. Co- Principal Investigator:

Name: Prof. Swapan Kumar Dolui &
Prof. Santanu Sharma

Institute : Tezpur University

5. Collaborating Organizations: None

Part A- Summary Report

1. Project Objectives:

Objectives as per the approved Project	Fully/Achieved/ Partially Achieved *(indicated shortfall)*	Reason for partial Achievement
(i) Assessment of performance of two arsenic and fluoride removal methods, viz., Arsiron Nilogon, Fluoride Nilogon and the modified Arsiron Nilogon developed by the PI's group, at different affected areas in the country	Fully achieved	NA
(ii) Development of automated domestic units of Fluoride Nilogon and Arsiron Nilogon and their user trial	Partially Achieved User trial could not be done	User trial could not be done due to COVID-19 pandemic
(iii) Development of a mercury removal method and its field trial	*Not done**	*NA**

** Not done because the PAC advised to remove this objective*

Deliverables:

Objectives as per the approved Project	Fully/Partially/ Not Achieved	Reason for partial Non-achievement
Mitigation of arsenic and fluoride problems in drinking water sources	Fully Achieved	NA *(Achieved as proposed)*
Proven technologies, viz., Arsiron Nilogon and Fluoride Nilogon for arsenic and fluoride removal for applications in different field conditions of the country through assessment of performance	Fully Achieved	NA *(Achieved as proposed)*
Automated domestic arsenic removal and fluoride removal units in plug-flow and continuous-flow modes, tested in the field trough user trial	Partially Achieved	User trial was not done due to COVID-19 pandemic

2. Specific Benefits/Outcome:

i). Patent, if any:

A patent application is being prepared on an automated dosing device of household Fluoride Nilogon. (*Two patents on the Arsiron Nilogon and Fluoride Nilogon methods submitted earlier were granted in February and November, respectively, in 2017*).

ii). Product/Process developed:

The project's main aim was to popularize two arsenic removal and fluoride removal technologies, namely, Arsiron Nilogon and Fluoride Nilogon, patented by the PI. We have

been able to popularize them to a notable extent especially in Assam and also in one district each in some other states like Chhattisgarh, Odisha, Rajasthan, Bihar, Uttar Pradesh and Karnataka. As an outcome of the present project, these extremely efficient, low-cost, sustainable, usable without electricity, safe and environment-friendly rural technologies are now being used by lakhs of people in the country.

Evaluation of the technologies in local conditions of different states including evaluation, especially study of suitability of limestone, of the locally available materials in different states have also been done successfully, which has helped implementation of the technologies in various states of India.

A large number of international and national NGOs (WaterAid India, UNICEF, Art of Living), government agencies (PHED, District Authorities, NPPCF), corporates (NRL, Ifield Energy, Probha Technotrade), schools and colleges, and individuals have been collaborating or supporting us in implementing Arsiron Nilogon and Fluoride Nilogon.

Not only the installed filters are sustainable, but also the implementation of the methods are expanding continuously with involvement of various organizations and self-interest of affected people with continued support from us.

In addition to the above, two products have been developed as was planned in the project:

(a) A semiautomatic compact household Arsiron Nilogon filter for removal of arsenic from drinking water based on a patented technology developed earlier by the PI's group.

(b) An automatic dosing device has been developed for dosing of phosphoric acid in household Fluoride Nilogon filter for removal of fluoride from drinking water based on a patented technology developed earlier by the PI's group.

iii). List of Publications arising from the project

(Indicate Impact Factors of the Journals: attach Copies of the Papers)

1) A study of suitability of limestone for fluoride removal by phosphoric acis-crushed limestone treatment, R. Mohan, R.K. Dutta, ***Journal of Environmental Chemical Engineering***, 8 (2020) 104410. ***Impact Factor = 4.300***

2) Continuous fixed-bed column assessment for defluoridation of waterusing Hap-coated, limestone, R. Mohan, R.K. Dutta, ***Journal of Environmental Chemical Engineering***, 8 (2020) 103840. ***Impact Factor = 4.300***

3) Removal of metals (Pb, Cd, Cu, Cr, Ni, and Co) from drinking water by oxidation-coagulation-absorption at optimized pH, Anup J. Bora, Robin K. Dutta, ***J. Water Process Engineering***, 31 (2019) 100839. ***Impact Factor = 3.465***

4) Field experience of Fluoride Nilogon: a method of fluoride removal from groundwater, R. Mohan, S. Gogoi, A.J. Bora, G. Baruah, S. Bordoloi, A.A. Ali, H.R. Sarma, R.K. Dutta, ***Current Science***, 118 (2020) 255-263. ***Impact Factor = 0.756***

5) Fluoride removal from water by limestone-sludge, R. Mohan, A.J. Bora, R.K. Dutta, ***Desalination and Water Treatment***, 112 (2018) 19-33. ***Impact Factor = 0.854***

iv). Linkages developed

The project has helped in developing the following linkages which have been giving results:

1	Water Aid India	Collaborating for implementation of Fluoride Nilogon and Arsiron Nilogon in various states
2	UNICEF	Collaborating in strengthening water quality testing in PHED labs and by Science Colleges in Assam
3	Art of Living	Collaborating for implementation of Fluoride Nilogon and Arsiron Nilogon in Karbi Anglong, Nalbari and Majuli districts in Assam
4	ZOA Netherlands	Exploring possibility of implementation of Fluoride Nilogon in Yemen
5	Samarthan, Chhattisgarh	Collaborating for implementation of Fluoride Nilogon in Chhattisgarh
6	RCDC, Odisha	Collaborating for implementation of Fluoride Nilogon in Odisha
7	SVYM, Karnataka	Collaborating for implementation of Fluoride Nilogon in Chhattisgarh
8	INREM	Planning for implementation of Fluoride Nilogon and Arsiron Nilogon in Assam and Bihar
9	Assam Sarba Siksha Abhiyan Mission	Supporting implementation of Fluoride Nilogon and Arsiron Nilogon in schools in Assam initiated by the Mission
10	Probha Technotrade, Bombay	Collaborating for developing a compact household Arsiron Nilogon filter for commercialization
11	IField Energy Pvt. Ltd, Jaipur	Process of Technology transfer of Arsenic and Fluoride removal to the company in in progress.
12	PHED Assam	Collaborating for implementation of large community Fluoride Nilogon systems in Karbi Anglong district and at household level in Baksa district of Assam
13	Numaligarh Refinery Ltd.	Collaborating for implementation of Arsiron Nilogon in some villages in Golaghat district in Assam with very good results
14	National Program for Prevention and Control of Fluorosis (NPPCF)	Collaborating for implementation of Fluoride Nilogon in Karbi Anglong and Karimganj districts of Assam.
15	Kudumbashree	Collaborating for implementation of Arsiron Nilogon in Biswanath district of Assam
16	SaciWaters	Collaborated in implementation of Arsiron Nilogon in Nalbari, Assam and Buxar, Bihar
17	About 80 Science Colleges in Assam	Collaborating for implementation of Arsiron Nilogon and Fluoride Nilogon technologies in Assam and also for Water Quality testing including arsenic and fluoride.
18	Gram Panchayat and autonomous regions	Collaborating for implementation of Arsiron Nilogon and Fluoride Nilogon technologies in Jorhat, Borpeta and Karbi Anglong districts in Assam

19	Many other NGOs in Assam	Collaborating for implementation of Arsiron Nilogon and Fluoride Nilogon technologies in Assam including IMPACT-NE (Majuli), Sanskar (Titabor), Helping Hand (Baksa), Seuj Dhara (Golaghat), Rotary Club (Guwahati), Baregaon SKKB Kendra & Haridev KKB Kendra (Charaideo)

v). Manpower trained, give details.

The following persons were trained well as manpower in the project:

Sl. No.	Name	Worked in project as	Current occupation
1	Mr. Rajkamal Mohan	JRF	Completed PhD with the PI at TU *Topic: A study of removal of fluoride from contaminated groundwater using calcium-containing materials*
2	Md. Asadulla Asraf Ali	JRF	Pursuing PhD with the PI at TU *Topic: Traditional Science*
3	Mr. Rituparna Saikia	JRF	Pursuing PhD with the PI at TU *Topic: Resource-oriented Sanitation*
4	Ms. Tushmita Das	JRF	Pursuing PhD with the PI at TU *Topic: Removal of Heavy metals*
5	Mr. Hridip Ranjan Sharma	JRF	Pursuing PhD in Deakin Univ, Australia
6	Mr. Pinku Gogoi	JRF	Pursuing PhD in NEIST, Jorhat
7	Mr. Krishnakamal Hazarika	JRF	Working as JRF at NEIST Jorhat
8	Md. Mahidul Islam	JRF	Working in PHED as District Associate
9	Mr. Abhijit Dutta	JRF	Working in an Oil Drilling Company

*There were 6 JRF positions but some of the students discontinued because the salary was only Rs. 12000/- per month.

3. Summary of significant S&T Achievements

(Provided in bullet form)

- As per objective of the project we have popularized and implemented two arsenic and fluoride removal technologies, namely Arsiron Nilogon and Fluoride Nilogon developed by the PI's group at TU, in arsenic and fluoride-affected areas of 15 districts in Assam and also in one district each in Chhattisgarh, Odisha, Karnataka, Bihar and Rajasthan.

- We have addressed some location specific problems, e.g., suitability of locally available limestone and use of locally available sand for filtration, arising in implementation of the technologies scientifically and solved them scientifically.

- Developed a compact household Arsiron Nilogon filter for removal of arsenic in collaboration with a Bombay-based company, Probha Technotrade, which is expected to be commercialized soon.

- Developed an automated dosing unit for household Fluoride Nilogon filter.

- Task force of Jal Jivan Mission (JJM) has recommended the two technologies for implementation in the quality affected areas of the country.

- Implementation of the two technologies is now promoted by several NGOs including Water Aid India, UNICEF, Art of Living and Government agencies including PHED Assam in three districts, District Authority of Buxar (Bihar).

- We have been able to attract CSR fund from Numaligarh Refinery for implementation of Arsiron Nilogon in four villages in Golaghat District in a pilot basis.

- Preparation of a large-scale 10000 L Fluoride Nilogon pilot unit by Ifield Energy Technology, Jaipur, is in progress along with technology transfer as non-exclusive right of both of the patents of Fluoride Nilogon and Arsiron Nilogon.

4. Project Budget *(Final)*

S. No.	Item	(Amounts in lakhs)			
		1st Year	2nd Year	3rd Year	Total
1.	Capital-				
	a) Atomic Absorption Spectrophotometer (with 5 year AMC) (no. 1)	30.00	-	-	30.00
	b) Ion meter (with ion selective electrodes) (no. 1)	3.00	-	-	3.00
	c) Peristaltic pumps (no. 3)	3.00	-	-	3.00
	d) Pulverizer (no. 1)	1.00	-	-	1.00
	e) Hot-air oven (no. 1)	1.00	-	-	1.00
	f) PC & Printer (no. 1)	1.00	-	-	1.00
A	**Total**	**39.00**			**39.00**
2.	Manpower				
	a) JRF (no.6)	9.504	9.504	9.504	28.512
3.	Other Costs (Workshop and Training Programs, Patenting)	11.00	2.00	4.00	17.00
4.	Consumables	2.50	1.50	2.00	6.00
5.	Travel	1.50	1.50	1.00	4.00
6.	Contingencies	1.50	0.50	1.00	3.00
7.	Overhead Charges	1.00	1.00	1.00	3.00
B	**Total**	**27.004**	**16.004**	**18.504**	**61.512**
	Total (A+B)	**66.004**	**16.004**	**18.504**	**100.512**

4. Suggestions for Utilization of Project Outcome, *(Give tangible road map, name specific Industrial Units)*

As per the main objectives of the project, we have popularized the two rural technologies, namely Arsiron Nilogon (for removal of arsenic, iron and other heavy metal ions from drinking water) and Fluoride Nilogon (for removal of fluoride and heavy metals) in some affected areas 15 districts of Assam and one district each in Chhattisgarh, Odisha, Bihar, Rajasthan, Karnataka and UP in collaboration with a large number of international and national NGOs and government agencies. Currently, we have also been providing technical support to schools in Assam in installation of Arsiron Nilogon and Fluoride Nilogon filters in response to a call by the Assam Sarva Siksha Abhijan Mission. The expansion works are still continuing, which need our technical support for training and installation of filters.

As a logical conclusion of the project, we can propose a Centre for Safe Water to continue technical support to various organizations, government agencies, companies and individuals in removal of arsenic, fluoride and other heavy metal contaminants from drinking water, and to do research on related water quality issues and offer courses and training on management of safe water.

The proposed Centre will also extend technical support to the companies, e.g., Technotrade (Bombay) and Ifield Energy Pvt Ltd (Jaipur) with whom processes of technology transfer is in progress for implementation of the Arsiron Nilogon and Fluoride Nilogon technologies is in progress. We intend to submit a proposal for the Centre for funding to the DST soon.

Date (Signature of PI)

PROJECT COMPLETION REPORT

Part B- Comprehensive Report

(The Comprehensive Report should be precise in details and self-contained)

1. Project Title: Decentralized water treatment for removal of arsenic, fluoride and Mercury from drinking water

2. Product/Process as an outcome of the project, identify Beneficiaries.

As per objective of the project we have mainly popularized and implemented two arsenic and fluoride removal technologies, namely Arsiron Nilogon and Fluoride Nilogon developed by the PI's group at TU, in arsenic and fluoride-affected areas of 15 districts in Assam and also in one district each in Chhattisgarh, Odisha, Karnataka, Bihar and Rajasthan. Implementation of the two technologies is now promoted in collaboration with several NGOs including Water Aid India, UNICEF, Art of Living and Government agencies including PHED Assam in three districts, District Authority of Buxar (Bihar). Task force of Jal Jivan Mission (JJM) has recommended the two technologies for implementation in the quality affected areas of the country. We have also addressed and solved some location specific problems, e.g., suitability of locally available limestone and use of locally available sand for filtration, arising in implementation of the technologies scientifically and solved them scientifically. In addition to these, we have developed two products/processes, viz., a semiautomatic household Arsiron Nilogon filter and an automatic dosing unit for household Fluoride Nilogon filter.

2.i. Designing of a compact semiautomatic household Arsiron Nilogon filter:

We have developed a compact semi-automatic household Arsiron Nilogon filter for removal of arsenic in collaboration with a Bombay-based company, Probha Technotrade.

The filter consists of two plastic coated stainless-steel chambers with three mechanical dozers for the three chemicals used mounted at the top. A blended membrane-ceramic filter candle is fitted with the upper chamber of the filter. The filtered water collected in the lower chamber is free from arsenic.

The chemicals, *viz*., 10% cooking soda solution, 5% potassium permanganate solution and 25% ferric chloride solution in water controlled by three individual mechanical switches. On pressing a switch, the required volume of the respective chemical drops into water to be treated.

The technical evaluation of the filter was supposed to be conducted together with adjustment of some operational parameters and techniques which was interrupted as the engineer could not visit Tezpur due to COVID-19 pandemic. Once it is completed, hopefully in few months, the filter should be available in the market.

Fig.2.i. Prototype of Arsiron Nilogon filter designed with Prabha Technotrade, Bombay

2.ii. Designing of an automatic dosing unit for household Fluoride Nilogon filter:

We have also developed an automated dosing unit for household Fluoride Nilogon filter. The plug-flow mode automated unit can hold 250mL of 8.5% phosphoric acid (PA) which is enough to treat about 536 L of fluoride contaminated water. A plastic bottle is used to store the acid. We have adjusted the automated unit so that it dispenses 7 mL of 8.5% PA to treat 15L of contaminated water in one batch since a household Fluoride Nilogon unit usually has a capacity of 15L per batch. However, the amount of PA dispensed can be changed with the help of a smartphone. The device is started as soon as the limestone reactor is filled with contaminated water. Once started, the device dispenses 7 mL of PA and then stops. It needs to be restarted for treating the next batch of fluoride contaminated water. A schematic diagram of the dosing unit for Fluoride Nilogon is shown in Fig. 2a. All the electronic components of the device are shown in Fig. 2b and the whole device is shown in Fig. 2c. The performance of the automated unit was tested in the laboratory and its performance was found to be highly encouraging.

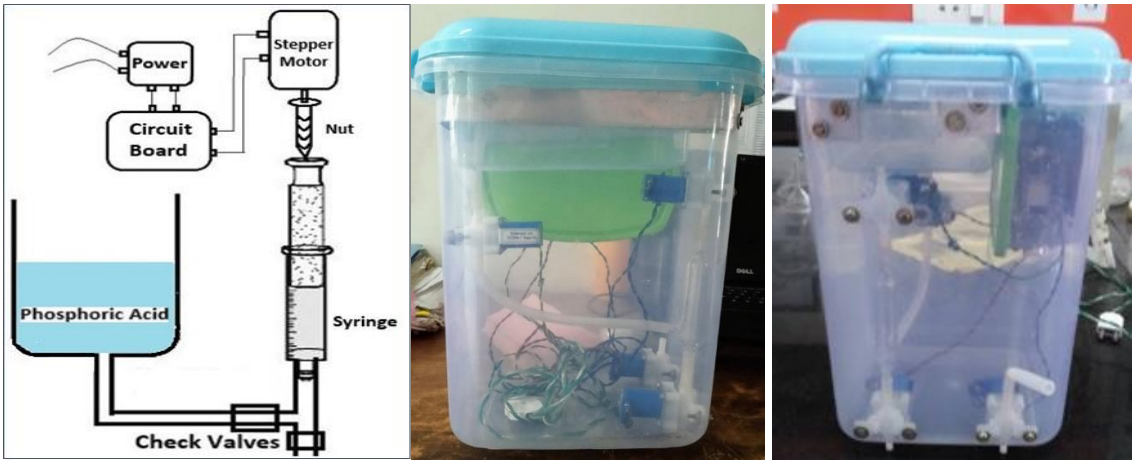

Fig. 2.ii. Schematic diagram, front and rear views of the dosing unit for fluoride Nilogon.

2.iii. Implementation of Fluoride Nilogon in Rajasthan, Chhattisgarh, Odisha and Karnataka:

(a) ***Rajasthan:*** In Jeerota village of Dausa district of Rajasthan, we have installed one 220 L small community Fluoride Nilogon filter and four 15 L household Fluoride Nilogon filters with a support from Mr. Rajesh Ghusinga, an Assistant Engineer, PHED, at Jaipur. Dr. Ashok Sarma (Principal, R.P Polytechnique, Jeerota), Mr. Satish Kumar (Sarpanch, Jeerota) and Mr. Kamlesh Kumar Sarma (Reporter) also extended help to us. The results of fluoride removal were very good. Friends of Lare Rameswar Lal Jajra also extended support to the work. The PI himself visited Merta and barunda from where the limestone was screened for suitability and collected for use and Jeerota for installation of the filters. Two project staffs, Mr. Rajkamal Mohan and Mr. Asadulla Asraf Ali also visited Merta and Barunda for the purpose of screening of limestone by evaluation of suitability which took almost a fortnight and also Jeerota for the installations.

Fig.2.iii.a A 500 L small community Fluoride Nilogon filter (top left) and three 15 L household Fluoride Nilogon filter at Jeerota village in Dausa district, Rajasthan.

Follow-up: All five filters are still being used and working well as informed by the users.

The work was halted by elections and then COVID-19 but can be restarted easily as already some 5 tons of limestone are stocked there. About 5 tons of very good quality limestone brought from Barunda is still stored at Jeerota at Gram Panchayat Sarpanch's house which can be used for making a large number of Fluoride Nilogon filters.

However, Ifield Energy Technology Ltd, Jaipur is going to implement Fluoride Nilogon in Rajasthan in large scale, for which, the process of non-exclusive technology transfer and piloting of a 10000 L unit is in progress. The company intends to implement the technologies in Rajasthan, UP, etc.

(b)***Chhattisgarh***: Nineteen household Fluoride Nilogon filters, of 15 L each batch capacity and two school Fluoride Nilogon filters, of 88 L each batch capacity, were installed in Kanker district in collaboration with WaterAid India and Samarthan, a local NGO before COVID-19. Mr. Anurag Gupta, from WaterAid India, who attended a workshop at Tezpur University under this project, took initiative in the work. One of the project staffs, Mr. Asadulla Asraf Ali stayed in Kanker for about two and half months to screen suitability of limestone and installing the filters. The PI also visited Kanker for the purpose.

As we could not find suitable limestone in time, some 3 tons of limestone were brought by the PI for installing the filters in Kankers and in also in Nuapada in Odisha. However, two filters could finally be installed in Kanker using limestone from a local source from Durg in Chhattisgarh. As per feedback, the users and the local NGOs in both states are highly satisfied and there is demand from villagers for the filter.

Follow-up: All 21 filters are being used and working well as have been informed by Samarthan, the local NGO. The user villagers are highly satisfied.

Fig.2.iii.b1. A temporary laboratory with one of the project staff (top left), some of the 19 (15 L) household Fluoride Nilogon filters ready for distribution to villagers in front of Dumarpani Panchayat office (top right) and two 88 L small community Fluoride Nilogon filters installed at M.S. Dumarpani Middle School (bottom left) and Dumali Middle School, Dumali (bottom right) in Kanker district of Chhattisgarh.

***Phase II of implementation of Fluoride Nilogon in Kanker, in 2021*:** **Inspired by the performance, currently, another 100 household Fluoride Nilogon filters are being installed** by Samarthan with support from WaterAid India with contributions from villagers with our help. The work was started during the extended period of the present project but we have been helping them till now for solving some issues arising for using local limestone collected from Durg, Chhattisgarh. Some issues developed in the beginning regarding installation and activation of the filters because of absence of an expert and lack of adequately trained people from the NGO. Therefore, the PI has somehow arranged to send one of his students, Mr. Saranga Baishya to Kanker, on March 2021 even though the present project was completed in Dec 2020, who has sorted out the issues in Kanker sorting out the issues.

Fig.2.iii.b2. Limestone from Durg being tested at PI's laboratory in TU (left) and Reactors of some of the 100 household Fluoride Nilogon filters of second phase being installed in Kanker.

(c) Odisha: Twenty-one household Fluoride Nilogon filters, of 15 L each batch capacity, were installed at Khariyar and Dharuapada villages near Khaira in Nuapada district of Odisha in collaboration with WaterAid India and Regional centre for Rural Development (RCDC), a local NGO before COVID-19. Mr. Anurag Gupta, from WaterAid India, who attended a workshop at Tezpur University under this project, took initiative in the work. One of the project staffs, Mr. Asadulla Asraf Ali stayed in Khaira for about a fortnight to screen suitability of limestone and installing the filters. The PI also visited the Khariyar and Dharuapada villages in Nuapada for the purpose. Inspired by the performance of the Fluoride Nilogon filters, the local NGO, RCDC is now expanding the installation of the filters.

Fig. 2.iii.c. Some of household Fluoride Nilogon filters installed at Khariyar and Dharuapada villages near Khaira in Nuapada district of Odisha.

Follow-up: All 21 filters are being used regularly. As informed by the local NGO, the user villagers are highly satisfied and the other villagers too want to have the filters with their own contribution. The NGO, RCDC, is contemplating for an expansion.

(d)***Karnataka:*** Water Aid India (Hyderabad), on the initiative of Mr. Hirudia Raj, in association with a local NGO, Swami Vivekananda Yuba Manch (YSVM) and our technical help has installed 35 household Fluoride Nilogon filters of 21 liters capacity at Gangabhairappanpalya village near Nelamangala in Outer Bangalore district. The work was started during the tenure of the present project but has been completed in March 2021. One of the students of the PI was there for one and half months for helping them in addition to a visit by the PI.

Difficulties faced: We could solve a problem arising due to increase of fluoride in water after filtration by sand-gravel filter though the removal was quite good after treatment in the reactor. Finally, we identified the defect in the sand and replaced the sand-gravel filter with a ceramic candle filter. There were some problems also due to damage of a standard chemical during transit from Tezpur to Bangalore but it was solved after procuring the same from Bangalore. Another difficulty was faced due to delay in arrival of limestone and other filter materials. However, all 35 filters could be installed well finally.

Fig. 2.iii.c. Fluoride-contaminated community water supply scheme of Gangabhairappan-palya village (left) and two of the 35 Fluoride Nilogon filters of 21 L capacity.

2.iv. Implementation of Arsiron Nilogon in Bihar, UP and Chhattisgarh:

(a) ***Bihar:*** On the initiative of Mr. Mayank Joshi, a Swaswa Bharat Prerak, the district administration of Buxar district, Bihar started implementation of Arsiron Nilogon under Poshan Abhiyaan at Anganwadi Centers of the district in collaboration with us. Saci WATERs water also extended support to the program in installation and demonstration. They also carried out a technical evaluation of the Arsiron Nilogon method with the help of the district PHED. The PI visited Buxar and delivered lecture-demonstration of Arsiron Nilogon at Brahmpur and Simri Block Offices.

Follow-up: The progress is however not satisfactory as the district authority is not implementing it effectively. There is also a need for awareness, motivation and training.

Fig. 2.iv.a1. Arsiron Nilogon filters at Brahmapur (left) and Simri (middle) block offices and demonstration of Arsiron Nilogon by Saci WATERs in Buxar, Bihar.

(b) Uttar Pradesh: With a local support from Mr. Sujoy Chakraverty, Principal, Swami Vivekananda Academy, Anantpur, we installed two 40 liters household Arsiron Nilogon filters at a Harijan village, Samar Basti, near Anantpur in Mirzapur district of UP.

Follow-up: As per telephonic information obtained from one of the users, Mr. Akhilesh Kumar, the filters are being used regularly. However, we were not able to expand the installations due to lack of local partner who could give time and later due to COVID-19.

Fig. 2.iv.b. Two 40-liter household Arsiron Nilogon filters installed at Samar Basti near Anantapur in Mirzapur District, UP

(c) Chhattisgarh: Water Aid India installed 20 household Arsiron Nilogon filters of 40 liter capacity in arsenic-affected Rajnandagaon district of Chhattisgarh in association with Lokshakti, a local partner NGO and in collaboration with us. We met some of the users who expressed satisfaction with the filter.

Fig. 2.iv.c. Some of the 20 Arsiron Nilogon filters of 40 liter capacity installed by WaterAid in association with Lokshakti, a local NGO partner with our collaboration in Rajnandagaon district, Chhattisgarh.

2.v. Implementation of Fluoride Nilogon in Assam

Fluoride Nilogon is being implemented in large scale in Karbi Anglong district of Assam both in household and community level. Three filters have been installed in Karimganj district also.

(a) Large community Fluoride Nilogon reactor for piped water supply schemes by PHED with our technical support:
  (i) At Ronkanthir and Kherani piped water supply schemes (PWSS)
(b) By the project team alone under the present project:
  (i) 3 small community Fluoride Nilogon filters at schools of 220 L batch capacity
  (ii) 25 household Fluoride Nilogon filters of 15 L batch capacity
(c) In collaboration with a Member of Karbi Anglong Autonomous Council (KAAC):
  (i) 20 household Fluoride Nilogon filters of 15 L batch capacity
(d) In collaboration with Art of Living and PHED with funding from KAAC:
  (i) 10 small community Fluoride Nilogon filters at schools of 88 L batch capacity
  (ii) **1680** (out of proposed 6500) household Fluoride Nilogon filters of 15 L batch capacity
(e) In collaboration with National Program for Prevention and Control of Fluorosis (NPPCF):
  (i) 3 household Fluoride Nilogon filters of 15 L batch capacity

2.v.a. Large community Fluoride Nilogon reactors for piped water supply schemes:

Two 40,000 L batch capacity Fluoride Nilogon reactors are being installed at Kherani and Ronkanthir piped water supply schemes near Manja in Karbi Anglong by PHED Assam. The construction was completed before the onset of the COVID-19 pandemic. Then there was some procedural delay in collection of limestone from Cement Corporation of India, Bokajan, Karbi Anglong. Now, the schemes are expected to be started working after the State Assembly election, in March-April, 2021. The PI has been extending all supports to the PHED in the work.

Fig. 2.v.a. Two such Fluoride Nilogon reactors (left) being installed at two 40000 L capacity pipes water supply schemes at Ronkanthir and Kheroni in Karbi Anglong district by PHED Assam. Limestone being collected for the reactors (right)

2.v.b. Installation of Fluoride Nilogon filters by the project team alone:

The project team started creating awareness and installing Fluoride Nilogon Filters on its own in Dengaon and Tekelangjun areas with the help of the Principal of a HS School (Mr. Jiban Pator) and a villager (Mr. Jaising Teron). A visiting PhD student of the PI from Ethiopia, Mr. Kebede Gamo also joined the team for some time. Mr. Kebede wanted to learn the method for application in his country.

The team installed 3 small community and 25 household Fluoride Nilogon filters on its own before a member of KAAC (Mr. Mukul Mahanta) supported us in installing 20 household Fluoride Nilogon filters in Deopani area of Karbi Anglong. The villagers crushed limestone and made bamboo or wooden filter stand with much enthusiasm.

Follow-up: All the household filters are being used regularly. We found some of the users to be very interested and satisfied. However the schools are not using the filters well may be because of lack of interest by the school authority. We observe this in many government schools.

Fig.2.v.b. Mr. Kebede Gamo (bald), a PhD student from Ethiopia on a hands on training of Fluoride Nilogon (30 Nov 2018) at Dengaon in Karbi Anglong, Assam when he was working at PI's laboratory in Tezpur University. Mr Kebede wants to use it in Ethiopia. Right: a 220L Fluoride Nilogon filter at Dengaon High English School installed by the project team.

2.v.c Large-scale implementation of Fluoride Nilogon in Karbi Anglong district of Assam:

Initiative of a member of Autonomous Council: We have helped in installation of 20 household Fluoride Nilogon filters with limestone and other filter materials arranged by the member, Mr. Mukul Mahanta at Japarajan village in Deopani area. The village is highly affected by fluoride. We also organized awareness and training program for the villagers. It was soothing to see how the villagers made bamboo and wooden stands and crushed limestone for the filters.

Fig. 2.v.c.1. Spontaneous involvement of villagers in installation of filters at Japarajan, Deopani, Karbi Anglong district, Assam

Collaboration with Art of Living, PHED and Karbi Anglong Autonomous Council KAAC

Art of Living installed a hopping 1680 household Fluoride Nilogon filters and 10 small community Fluoride Nilogon filters at schools before COVID-19 outbreak in collaboration with us which was funded by Karbi Anglong Autonomous Council (KAAC) through PHED. They are now preparing for another 500 filters.

Fig. 2.v.c.2. Clockwise from middle left: Karbi women sieving and collecting limestone, filter materials stored at a school, Mr. Mateo Keenan an Art of Living member demonstrating Fluoride Nilogon, a 88 L Small community Fluoride Nilogon filter at a school and some of the 15 L household Fluoride Nilogon filters of the 1680 installed at Tekelangjun area in Karbi Anglong, Assam by a joint venture by Art of living, PHED, LAAC and the project team.

This program was initiated with submission of a proposal by three art of living members from Karbi Anhglong, namely, Ms. Neelakshi Deka, Mr. Longbir Ingti and Mr. Atanu De in collaboration with the PI to KAAC. Later, the implementation was however led by Mr. Bishnu Prakash and assisted among others by four South American members of Art of Living. The program was inaugurated by Mr. Haren Sing Bey, MP from Diphu. The fund was provided by KAAC through PHED.

Follow-up: A survey with sample size of 75 random houses conducted by Art of Living in Sept 2020 revealed that 62 families (82.6%) were using the filter properly. 13 houses were not interested and not using the filters anymore. Reason is lack of interest, random usage or improper maintenance of the buckets, lost acid by household or using the filters to store groceries or clothes, etc.

We feel, this has happened because of hurriedly installing the filters without creating enough awareness, motivation and training. The Art of Living leadership was more interested in a big inauguration program with the Governor of Assam as the chief guest and religious activities than any awareness and training though there was some fund earmarked for awareness and training. Considering an urgent need of training before installation we organised a training program and went to the site but received lukewarm response from Art of Living. Then we discussed the matter with the local PHED and organized a training program for 25 PHED personnel at Tezpur University. Though ultimately 21 persons from Art of Living also participated in the workshop which was very meaningful but was not enough.

2.vii. Implementation of Arsiron Nilogon in Assam by NGOs, Corporate, Academic Institutes, etc., with support of the project team:

(a) NGOs:

A large number of NGOs have been installing and popularizing Arsiron Nilogon in Assam. Among them, Art of Living (Guwahati, Majuli and Nalbari branches), IMPACT-NE (Majuli), Sanskar (Jorhat) Gamkharu Gramya Sangathan (Jorhat), Helping Hand (Baksa), Baregaon SKKB Kendra and Haridev KKB Kendra (Charaideo), Bandhan (Majuli and Sibsagar), SEWA (Majuli), Seuj Dhara Development Society (Golaghat), Patidarrang MJ Sangha (Darrang) and Kudumbashree (Biswanath) are most active.

Art of Living under leaderships of Mr. Lai Madhukalya and Mr. Amarendra Kalita have installed and helped in installation of hundreds of households and about 30 small community Arsiron Nilogon filters in Majuli and Nalbari districts, respectively. Some of the filters were funded by its central office in Guwahati, initiated by Late Cornel Dr. Mahananda Medhi.

IMPACT-NE, led by Mr. Nilomoni Gayan and Dipankas Hazarika has installed over 100 household and 10 small community Arsiron Nilogon filters including two for police stations in Majuli. They have exhibited Arsiron Nilogon in two exhibitions including one in Assam State Children Science Congress meet.

Sanskar, led by Mr. Prasenjit Rajkhowa installed over 550 household and small community Arsiron Nilogon filters in Titabor area of Jorhat. Ms. Minakshi Bora from Gamkharu Gramya Sangathan also have installed over 15 Arsiron Nilogon filters.

Seuj Dhara Development Society popularized and installed over 30 household and small community Arsiron Nilogon filters in Golaghat district. Baregaon SKKB Kendra, led by Mr. Pushpa Gogoi has popularized and installed over 50 household Arsiron Nilogon filters in Charaideo district.

Fig. 2.vii.a. Arsiron Nilogon filters and awareness programs by various NGOs often without our involvement.

(b) Schools and Colleges:

Some Schools, namely, Uranpakhi Bhavan (Aathkhelia, Golaghat), Jatiya Bidyalay (Lachanga, Borpeta) and Kakadonga Higher secondary School have been popularizing Arsiron Nilogon by assigning it as a science project to students. They send the filter home for using after evaluation. They have also been installing filters and organizing awareness programs. Some colleges, especially, Kaliabor College (Nagaon), Nabajyoti College (Borpeta) and LTK College, Lakhimpur have been installing and popularizing Arsiron Nilogon filters through awareness programs and seminars on Arsiron Nilogon on their own. Some schools and colleges collect and send water samples for testing of arsenic at TU.

Dengaon Higher Secondary School in Karbi Anglong has been greatly supporting us in popularizing Fluoride Nilogon in Karbi Anglong since beginning (2013). Several household and School Fluoride Nilogon filters were installed on the initiative of its Principal Mr. Jibon Chandra Pator.

Students have been presenting Arsiron Nilogin and Fluoride Nilogon in Science exhibition and wining 1st prize in science competitions including Children Science Congress and Science Conclave of Guwahati IIT.

Fig. 2.vii.b1. Spontaneous School Science Projects on Arsiron Nilogonb

Fig. 2.vii.b2. Awareness Program, Workshop and Seminar organized by Pashim Pubthoriya High School, Kaliabor College, Nagaon and LTK College, Lakhimpur.

(c) Three Gram Panchyats in Borpeta, Nalbari and Jorhat (Namchungi) districts of Assam have been installing Arsiron Nilogon filters and organizing awareness camps on Arsiron Nilogon. Dakshin-Pub Pokagaon GP, Borpeta and Dakshin Khetri Darmapur GP, Nalbari have installed 22 and 5 household Arsiron Nilogon filters, respectively.

Fig. 2.vii.c. Some filters installed by the Gram Panshayats in Borpeta and Nalbari districts

(d) By trained Volunteers:

There are some trained volunteers, mostly school teachers, who have been popularizing and installing household and small community Arsiron Nilogon filters in their nearby areas and villages in some districts in Assam. Some most active volunteers are: Mr. Sadulla Ali (Kaithalkuchi, Nalbari), Mr. Ajit Saikia (Deodiati, Majuli), Mr. Ziarul Islam (Kalgachia, Borpeta), Mr. Prasanna Bhuyan (Kakadonga, Golaghat), Mr. Samiran Saikia (Kathamiya, Majuli), Mr. Pranjit Das (Balitara, Nalbari), Mr. Dambaru Dihingia (Silapathar, Dhemaji), Mr. Bito Ali Hazarika (Salana, Nagaon), Mr. Papumoni Hazarika (Kuruabahi, Golaghat), Mr. Abhishek Gogoi (Jorhat), etc. On the other hand, Mr. Joysing Teron and Mr. Chandra

Ronghang, etc., from Karbi Anglong have been greatly helping us in popularizing and installing household Fluoride Nilogon filters in Karbi Anglong.

Fig. 2.vii.d. Some of the volunteers trained by us are creating awareness and installing hundreds of Arsiron Nilogon and Fluoride Nilogon filters in villages and schools in various districts in Assam. **We consider this as a major success of the present project.**

(e) With support from Numaligarh Refinery Ltd:

Numaligarh refinery is coming forward to support installation of Arsiron Nilogon filters at 320 households at four severely arsenic-affected villages, viz., Chinakan, Adarsha Gaon, Rongagorah and Singadariya at Kuruabahi area in Golaghat district of Assam as a pilot project with CSR funding. The beneficiary residents are extremely happy to have the filter and are using them with much interest. There are growing high demand for the filters by others.

Fig. 2.vii.d. Implementation of Arsiron Nilogon with CSR fund of Numaligarh Refinery Ltd.

2.viii. Workshops & Training Programs:

A major part of the project fund was allocated for popularizing Arsiron Nilogon and Fluoride Nilogon among rural people countrywide through Workshops and Training programs. We have organized much more such programs than planned initially which was possible due to collaboration by a large number of organizations including NGOs and academic institutes.

The workshops and training programs were organized much more than stated in the project proposal. The workshops and training programs organized in physical mode before advent of COVID-19 have been included in previous three annual progress reports. The achieved high popularity of Arsiron Nilogon and Fluoride Nilogon technologies among rural people across states have been the results of the workshops and training programs organized under the present program.

We started working in the midst of COVID-19 and have organized online meetings on Zoom platform. The project assistants and our trained volunteers also started installation of

filters in their own districts as soon as movement within own district was allowed. The online Workshops and Training programs, which lasted for 1-2 hours, are listed below:

(a) 1st Online meeting (Zoom Platform) during COVID-19 Pandemic

Sl. No.	Event, Date	Objectives	Participants	Outcome
1	Sustainability of the recently installed Fluoride Nilogon filters at Khaira, Odisha and way forward: 4-07-2020	How to sustain Fluoride Nilogon filters already installed at Khaira, Odisha	5 from RCDC and TU group	All filters are working well. Arrangement has been made for continued supply of phosphoric acid. Planned for expansion as wanted by other villages.
2	Fluoride Nilogon in Chhattisgarh: 29-08-2020	How to sustain Fluoride Nilogon filters already installed in Kanker & its expansion in Chhattisgarh	8 from WaterAid, Samarthan and TU	All filters are working well. Arrangement has been made for continued supply of phosphoric acid. Planned for expansion as wanted by other villages with their contribution using local limestone (to be tested at TU).
3	Arsiron Nilogon Training Program for Art of living, Saci Waters Assam and Gram Panchayats from Nalbari and Borpeta: 8-09-2020	Training on Arsiron Nilogon and installation of filters	10 from the GPs, Art of Living, Saci WATERs & TU	The GP's & Saci WATERs to install Arsiron Nilogon filters with the help of trained volunteers from Art of Living
4	Arsiron Nilogon for solving Arsenic problem of Majuli: 20-09-2020	Awareness on Arsenic and Training on Arsiron Nilogon Filter.	22 from trained volunteers and others from Majuli and TU	Installation was restarted after halt due to COVID-19
5	Arsiron Nilogon for Arsenic affected	Awareness on arsenic contamination	25 from PHED lab personnel, Dist. Elementary	The water from all schools of the district to be tested for arsenic

	Dhemaji District: 11/10/2020	in Dhemaji district and remediation using Arsiron Nilogon	Education Officer (DEEO), Cluster Resource Centre Coordinators (CRCC), Teachers of schools & colleges, villagers	and Arsiron Nilogon filters to be installed where necessary. DEEO also suggested another meeting to be organized for schools as per call by **Axom Sarba Siksha Abhiyan Mission**
6	Arsiron Nilogon for Arsenic affected Golaghat District: 17-10-2020	Awareness on arsenic contamination in Golaghat district and remediation using Arsiron Nilogon	35 from trained volunteers, teachers, District Elementary Education Officer & TU	The water from all schools of the district to be tested for arsenic and Arsiron Nilogon filters to be installed where necessary as per call by **Axom Sarba Siksha Abhiyan Mission**

(b) <u>Offline Workshop held after the pandemic period:</u>

We have organized three offline meetings when the COVID-19 restrictions were relaxed:

Sl. No.	Event, Date	Objectives	Participants	Outcome
1	Arsenic in Groundwater and Mitigation through Scientific way: 17-11-2020	Awareness on arsenic contamination in Dhemaji district and remediation using Arsiron Nilogon	52 from PHED lab personnel & Engineers, School & College teachers, principal, villagers and TU	More teachers and villagers got interested in Arsiron Nilogon
2	Workshop on Arsenic contamination of drinking water and its testing and Removal by Arsiron Nilogon: 21-11-2021 (Morning)	The Inspector of Schools Golaghat collaborated in organizing the Workshop with an aim of installation of Arsiron Nilogon filters in all schools of Golaghat district.	45 from CRCCs and Science Teachers of the Schools, IS, DEEO, etc., & 2 from TU	They collected & got 40 water samples from schools for arsenic at Tezpur University. They are also going to testing of water & install filters at all affected schools in the district.
3	Awareness and training on	Residents of Jyoti Nagar in Golaghat	20 villagers & 2 from TU	The villagers resolved to install

	Arsiron Nilogon: 21-11-2021 (Afternoon)	for installation of household filters after PHED's PWSS Arsiron Nilogon was stopped		household Arsiron Nilogon filters.

(c). <u>Workshop held during 3rd Year</u>

One Regional Workshop and 23 small training programs were held.

Sl. No.	Date	Description
1	27/7/2019	***Regional Workshops*** **Workshop on Arsiron Nilogon and Fluoride Nilogon** Venue: Tezpur University Council Hall Participants: 250 prospective promoters from NGO's, villages and Educational Institutes from Assam Rajasthan, UP and Chhattisgarh with many participants from various international and National NGOs. Many of the participants started working on popularization of Arsiron Nilogon and Fluoride Nilogon in various districts of Assam and various parts of the country.
		Small Programs
2	6/5/2019	**Small Workshop on Arsiron Nilogon** Venue: Tezpur University Participants: 11 volunteers and prospective volunteers from some NGO's and Namchungi Gram Panchayat of Jorhat District
3	29/5/2019	**Training Program on Arsiron Nilogon and Fluoride Nilogon** Venue: NERIWALM (Lecture) & TU (Demonstration) Collaborator: NERIWALM, Tezpur Participants: 15 NGO activists from Assam
4	17/6/2019	**Workshop on Arsiron Nilogon** Venue: Namchungi Gaon Panchayat Premise, Titabor, Assam Collaborator: Sanskar, Namchungi, Titabor Participants: 70 villagers and Gaon Panchayat members
5	10/7/2019	**Workshop on Arsiron Nilogon and Fluoride Nilogon** Venue: Lakhimpur College (Autonomous) Participants: 100 students and teachers

6	19/7/2019	**Training on Arsiron Nilogon** Venue: Balipariya, Bogar Gaon, Titabor, Jorhat Organized by: Gamkharu Gramya Sangathan, Titabor Participants: 30 local women local mainly
7	22/8/2019 (Half day)	**Demonstration on Arsiron Nilogon and Fluoride Nilogon** Venue: Dept. of Chemical Sciences, Tezpur University Collaborator: NERIWALM, Tezpur Participants: 22 Lab Assistants of PHED, NPPCF, Researchers
8	24/8/2019	**Awareness Program on Arsiron Nilogon & Fluoride Nilogon** Venue: Bapuji H. School, Salona, Nagaon District Collaborator: Kaliabor College, Nagaon Participants: 150 villagers, teachers and students, Tea Garden managers, College teachers, Sub-divisional official, etc.
9	30/8/2019	**Small Workshop on Arsiron Nilogon** Venue: Arunoday High School, Bhalukmara, Majuli Collaborator: Impact NE, Majuli Participants: 50 students and teachers
10	7/9/2019	**Small Training Program on Fluoride Nilogon** Venue: Bhelughat, Bagpani, Karbi Anglong Participants: 10 villagers from Bhelughat
11	13/9/2019	**One-day Training Program on Arsiron Nilogon** Venue: Dept. of Chemical Sciences, Tezpur University 20 NGO members from Baksa and Darrang districts
12	24/9/2019	**Inauguration of Fluoride Nilogon in Karbi Anglong by Art of Living** Venue: Ashram, Art of Living, Diphu Collaborator: International Center of Art of Living, Diphu Participants:100 including MP Mr. Haren Sing Bey and EM PHED of Karbi Anglong Autonomous Council, Assam **NB: MP Mr. Bey inaugurated installation of 1680 household/school Fluoride Nilogon filters**.
13	3/10/2019	**Awareness and Workshop on Arsiron Nilogon** Venue: Block Office, Brahmpur, Buxar, Bihar Collaboration: Buxar District Authority & Saci WATERs Participants: 30 Anganwadi workers, Block and district officials
14	3/10/2019	**Awareness and Workshop on Arsiron Nilogon** Venue: Block Office, Simri, Buxar, Bihar Collaboration: Buxar District Authority & Saci WATERs Participants: 30 Anganwadi workers, Block and district officials

15	8/11/2019	**Workshop on Water Quality Testing and Training on Arsiron Nilogon and Fluoride Nilogon for PHED lab personnel of Assam** Venue: Dept. of Chemical Sciences, Tezpur University Collaboration: UNICEF Assam Participants: 70 Chemists, Assistant Chemists and Lab Assistants of PHED, Assam
16	7/12/2019	**One-day Training Program on Fluoride Nilogon** Venue: Tezpur University Participants: 50 including PHED personnel from Karbi Anglong including Executive Engineer of Howraghat Division and members of Art of Living, Karbi Anglong
17	8/12/2019	**Awareness on Arsenic Contamination and Its Removal by Arsiron Nilogon** Venue: Sapekhati High School Collaborators: Local people Participants: 200 villagers and students
18	20/12/2019	**Awareness on Arsenic poisoning and Arsiron Nilogon** Venue: Shiva Mandir, Patidarrang, Darrang district, assam Collaborator: Local people of Patidarrang Participants: 100 villagers
19	31/12/2019	**One-day Training Program on Arsiron Nilogon** Venue: Dept. of Chemical Sciences, Tezpur University Participants: 25 students from Chayduar College, Gohpur and Darrang College, Tezpur
20	27/1/2020 Forenoon	**Arsenic Contamination & its Removal by Arsiron Nilogon** Venue: J.B. College, Jorhat Collaborator: Department of Chemistry, J.B. College Participants: 100 Students, teachers and the Principal
21	27/1/2020 Afternoon	**Arsiron Nilogon** Venue: Asom Mahotsav, Court Field, Jorhat Collaborator: Organizers of Asom Mahotsav Participants: 200 people
22	3/2/2020	**Meeting with members of Task Force of JJM, New Delhi & PHED Engineers of Tezpur on Arsiron Nilogon & Fluoride Nilogon** Venue: Department of Chemical Sciences, Tezpur University Participants: 3 Task Force Members & 7 Engineers
23	5/2/2020	**Training on Arsiron Nilogon** Venue: Department of Chemical Sciences, Tezpur University Participants: 15 NGO members

24	8/2/2020	**Workshop on Water Quality Testing and Training on Arsiron Nilogon and Fluoride Nilogon for PHED lab personnel of Assam** Venue: Dept. of Chemical Sciences, Tezpur University Collaboration: UNICEF Assam Participants: 25 Assistant Chemists and Lab Assistants of PHED, Assam

(d). <u>Workshop held during 2nd Year</u>

There were two Regional Workshops and 32 Small Workshop or Training Programs

Sl. No.	Date	Description
		Regional Workshops = 2
1	9/2/2019	**Workshop on Arsiron Nilogon and Fluoride Nilogon** Venue: Tezpur University Participants: 60 prospective promoters from NGO's, villages and Educational Institutes from Assam
2	19/2/2019	**Workshop on Arsiron Nilogon** Venue: Kaliabor College, Kaliabor, Nagaon, Assam Participants: 100 students, teachers and villagers Organized by: Kaliabor College, Kaliabor, Nagaon & Department of Chemical Sciences, Tezpur University (jointly)
		***Small Workshop or Training Programs* = 32**
3	8/4/2018	Venue: Balitara, Nalbari Participants: 65 local villagers
4	22/4/2018	Venue: Kakadonga H.S. School, Golaghat Participants: 100 villagers, Teachers and students
5	1/5/2018	Tezpur University Participants: 25 volunteers and prospective volunteers from NGO's, villages and Educational Institutes
6	5/5/2018	Kakadonga H. School, Golaghat Participants: 150 villagers, teachers and students
7	22-23/5/2018	Tezpur University Participants: 25 volunteers from Art of Living, Karbi Anglong, Assam

8	22/7/2018 Morning	LP School, Guwalgaon, Majuli Participants: 30 villagers and teachers
9	22/7/2018 Afternoon	Chelek Gaon, Majuli Participants: 50 villagers (mostly women) Collaboration: Abakash Majuli (NGO)
10	5/8/2018	Kamar Bondha, Golaghat Participants: 65 local women Collaboration: Seuj Dhara Development NGO
11	14/8/2018	Leteripar, Dhing, Nagaon Participants: 25 villagers
12	27/8/2018	Rongkanthir, Manja, Karbi Angling Participants: villagers and PHED personnel Collaboration: PHED, Karbi Anglong Autonolous Council, Assam
13	29/8/2018	Sri Sri Kamalabari Satra H. School, Titabor, Jorhat, Majuli Participants: 100 villagers, teachers and students
14	6/9/2018	Kendukuchi, Nalbari Participants: 55 villagers Collaboration: Art of Living, Nalbari
15	26/9/2018	Sarik Teron village, Karbi Anglong, Participants: 25 villagers from Bagpani area
16	6/10/2018	Balitara, Nalbari Participants: 40 NGO members and villagers from Balitara and Kalgachia
17	1/11/2018	Jeerota, Dausa, Rajasthan Participants: 45 local villagers Collaboration: Sarpanch of Jerota Gram Panchayat
18	3/11/2018	Rajesh Pilot Polytechnic College, Jerota, Dausa, Rajasthan Participants: 150 students and teachers Collaboration: Rajesh Pilot Polytechnic College, Jerota, Dausa, Rajasthan
19	10/11/2018	Dakhinpat Satra, Majuli Participants: 30 villagers Collaboration: Art of Living, Majuli
20	20/11/2018	Bokolai LP School, Golaghat Participants: 100 villagers and school children

		Collaboration: Seuj Dhara Development NGO
21	22/11/2018	Garamur Bar Satra, Majuli Participants: 100 villagers Collaboration: Bandhab, Majuli (NGO)
22	2/12/2018	Dengaon, Karbi Anglong, Assam Participants: 30 villagers from Dengaon area
23	31/12/2018	Aathkhelia Uran Pakhi School, Golaghat, Assam Patricipants: 50 Students and teachers Collaboration: Aathkhelia Uran Pakhi School
24	13/1/2019	Dorodi Chuk, Deopani, Karbi Anglong Participants: 50 MAC, villagers, teachers, and PHED personnel Collaboration: A Member of Karbi Anglong Autonomous Council
25	25/1/2019	Guileja, Kalgachia, Borpeta, Assam Villagers: 40 local villagers
26	26/12/2019	Lasanga Jatiya Bidyalay, Kalgachia Participants: 300 villagers, teachers and students Collaborator: Lasanga Jatiya Bidyalay, Kalgachia
27	9/2/2019	Aleni banhjengoni Satra, Kathamiya, Majuli Participants 20 villagers Collaboration: Art of Living, Majuli
28	11/2/2019	Barbari, Garmur, Majuli Participants: 20 villagers Collaboration: Bandhab, Majuli (NGO)
29	13/2/2019	LP School, Gualgaon, Majuli Participants: 60 villagers, teachers and students Collaboration: Impact NE (NGO)
30	15/2/2019	Harighat Rangoli Pahar H. School, Bhakatiduwar Participants: 50 students, teachers and villagers Collaboration: Art of Living, Majuli
31	25/2/2019	Cooperative Department Office, Majuli Participants: 23 villagers and office staff
32	26/2/2019	Veterinary Department Office, Majuli Participants: 18 Officer and staff
33	1/3/2019	Gargaon College, Sibsagar, Assam Participants: 200 students and teachers

34	3/3/2019	Collaboration: Department of Chemistry & Department of Geology, Gargaon College Barbara Gaon, Jorhat Participants: 20 villagers

(e). <u>Workshop held during 1st Year</u>

Sl. No.	Date	Progress
1	24-25/2/2018	***National Workshop on Arsiron Nilogon and Fluoride Nilogon*** Venue: Tezpur University Participants: a total 725 participants from Assam, Arunachal, Meghalaya, Bihar, Rajasthan, Andhra, Chhattisgarh, Maharashtra, etc.
2	28/1/2018	***Regional Workshop on Arsiron Nilogon and Fluoride Nilogon*** Venue: Aryan International School, Varanasi Collaboration: Aryan International School, Varanasi & Swami Vivekananda Academy, Anantapur, Mirzapur Participants: 75 participants from UP and Bihar including the school.
3	10/9/2017	***A Small Awareness cum Training Program*** Venue: Tezpur University Participants: 25 promoters and prospective promoters from NGO's, villages and Educational Institutes.

2.ix. Research works on improvement of the methods, user trial and suitability of limestone List of Publications arising from the project

We have done some research works in addition to testing of water samples for installation of filters and to monitor performance of Arsiron Nilogon and Fluoride Nilogon filters in Assam and other states. The major works were:

(a) ***Study of simultaneous removal of arsenic, iron, manganese and other heavy metals by Arsiron Nilogon method:*** The results of work have been very exciting as the Arsiron Nilogon method has been found to remove all heavy metals together with arsenic in addition to regulating the pH without affecting the potability of the water. The results have been published in the form of the following research paper:

(i) Removal of metals (Pb, Cd, Cu, Cr, Ni, and Co) from drinking water by oxidation-coagulation-absorption at optimized pH, Anup J. Bora, Robin K. Dutta, J. Water Process Engineering, 31 (2019) 100839. *Impact Factor = 3.465*

(b) ***Study of suitability of limestone for Fluoride Nilogon:*** The study reveals the behaviour of different limestone samples collected from seperate geographical locations of India in fluoride removal from groundwater by PACLT method. It turned out that the limestone samples with higher BET surface area, total pore volume, and lower density, average pore diameter have a higher capacity for fluoride removal. Also, higher amount of Al and Fe were found in these samples, which may have played a decisive role in their fluoride removal and the final pH of treated water. PHREEQC supports this observation by predicting a decrease in pH of the treated water and an increase in the precipitation of fluorite and in situ formed HAp, with increasing Al_2O_3 and Fe_2O_3 impurities of limestone. Moreover, the analysis has predicted that high amount of CaO in limestone will reduce defluoridation. A paper has been published on this:

(i) A study of suitability of limestone for fluoride removal by phosphoric acid-crushed limestone treatment, R. Mohan, R.K. Dutta, Journal of Environmental Chemical Engineering, 8 (2020) 104410. *Impact Factor = 4.300*

(c) ***Field experience of Fluoride Nilogon:*** We were waiting for about six years for the limestone beds of Fluoride Nilogon filters installed for user trial to exhaust to do regeneration study but there was no sign of any deterioration of the performance of the limestone beds for six years. So finally we has decided to publish the field experience and thinking the results to be of great importance, we had chosen to publish in India in Ciurrent Science:

(i) Field experience of Fluoride Nilogon: a method of fluoride removal from groundwater, R. Mohan, S. Gogoi, A.J. Bora, G. Baruah, S. Bordoloi, A.A. Ali, H.R. Sarma, R.K. Dutta, Current Science, 118 (2020) 255-263. *Impact Factor = 0.756*

(d) Two other related studies on fluoride removal have been made:

(i) Continuous fixed-bed column assessment for defluoridation of water using Hap-coated, limestone, R. Mohan, R.K. Dutta, Journal of Environmental Chemical Engineering, 8 (2020) 103840. *Impact Factor = 4.300*

(ii) Fluoride removal from water by limestone-sludge, R. Mohan, A.J. Bora, R.K. Dutta, Desalination and Water Treatment, 112 (2018) 19-33. *Impact Factor = 0.854*

(e) ***List of Publications arising from the project***

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2) Continuous fixed-bed column assessment for defluoridation of water using Hap-coated, limestone, R. Mohan, R.K. Dutta, Journal of Environmental Chemical Engineering, 8 (2020) 103840. *Impact Factor = 4.300*

3) Removal of metals (Pb, Cd, Cu, Cr, Ni, and Co) from drinking water by oxidation-coagulation-absorption at optimized pH, Anup J. Bora, Robin K. Dutta, J. Water Process Engineering, 31 (2019) 100839. *Impact Factor = 3.465*

4) Field experience of Fluoride Nilogon: a method of fluoride removal from groundwater, R. Mohan, S. Gogoi, A.J. Bora, G. Baruah, S. Bordoloi, A.A. Ali, H.R. Sarma, R.K. Dutta, Current Science, 118 (2020) 255-263. *Impact Factor = 0.756*
We consider this as the best paper among all these and intentionally we have published it in an Indian journal.

5) Fluoride removal from water by limestone-sludge, R. Mohan, A.J. Bora, R.K. Dutta, Desalination and Water Treatment, 112 (2018) 19-33. *Impact Factor = 0.854*

2.x. Linkages developed

The following linkages developed during the project period have been giving results:

1	UNICEF	Collaborating in strengthening water quality testing in PHED labs and by Science Colleges in Assam
2	Water Aid India	Collaborating for implementation of Fluoride Nilogon and Arsiron Nilogon in various states
3	Art of Living	Collaborating for implementation of Fluoride Nilogon and Arsiron Nilogon in Karbi Anglong, Nalbari and Majuli districts in Assam
4	Samarthan, Chhattisgarh	Collaborating for implementation of Fluoride Nilogon in Chhattisgarh
5	RCDC, Odisha	Collaborating for implementation of Fluoride Nilogon in Odisha
6	SVYM, Karnataka	Collaborating for implementation of Fluoride Nilogon in Chhattisgarh
7	INREM	Planning for implementation of Fluoride Nilogon and Arsiron Nilogon in Assam and Bihar
8	Assam Sarba Siksha Abhiyan Mission	Supporting implementation of Fluoride Nilogon and Arsiron Nilogon in schools in Assam initiated by the Mission
9	Probha Technotrade, Bombay	Collaborating for developing a compact household Arsiron Nilogon filter for commercialization
10	IField Energy Pvt. Ltd, Jaipur	Process of Technology transfer of Arsenic and Fluoride removal to the company in in progress.
11	PHED Assam	Collaborating for implementation of large community Fluoride Nilogon systems in Karbi Anglong district and at household level in Baksa district of Assam
12	Numaligarh Refinery Ltd	Collaborating for implementation of Arsiron Nilogon in some villages in Golaghat district in Assam
13	National Program for Prevention and Control of Fluorosis (NPPCF)	Collaborating for implementation of Fluoride Nilogon in Karbi Anglong and Karimganj districts of Assam.

14	Many small NGOs in Assam	Collaborating for implementation of Arsiron Nilogon and Fluoride Nilogon technologies in Assam
15	Kudumbashree	Collaborating for implementation of Arsiron Nilogon in Biswanath district of Assam
16	About 80 Science Colleges in Assam	Collaborating for implementation of Arsiron Nilogon and Fluoride Nilogon technologies in Assam and also for Water Quality testing including arsenic and fluoride.
17	Gram Panchayat and autonomous regions	Collaborating for implementation of Arsiron Nilogon and Fluoride Nilogon technologies in Jorhat, Borpeta and Karbi Anglong districts in Assam

2.xi. Manpower trained.

The following persons were trained well as manpower in the project:

Sl. No.	Name	Worked in project as	Current occupation
1	Mr. Rajkamal Mohan	JRF	Completed PhD with the PI at TU *Topic: A study of removal of fluoride from contaminated groundwater using calcium-containing materials*
2	Md. Asadulla Asraf Ali	JRF	Pursuing PhD with the PI at TU *Topic: Traditional Science in Manuscript Writing of Assam* To be completed in a year.
3	Mr. Rituparna Saikia	JRF	Pursuing PhD with the PI at TU *Topic: Resource-oriented Sanitation* To be completed in two years
4	Ms. Tushmita Das	JRF	Pursuing PhD with the PI at TU *Topic: Removal of Heavy metals* To be completed in two years
5	Mr. Hridip Ranjan Sharma	JRF	Pursuing PhD in Deakin University, Australia.
6	Mr. Pinku Gogoi	JRF	Pursuing PhD in NEIST, Jorhat.
7	Mr. Krishnakamal Hazarika	JRF	Working as JRF at NEIST Jorhat.
8	Md. Mahidul Islam	JRF	Working in PHED as District Associate.
9	Mr. Abhijit Dutta	JRF	Working in an Oil Drilling Company.

*There were 6 JRF positions. Some of the JRF's discontinued to join elsewhere as the fellowship was only Rs. 12000/- per month.

2.xiii. Media coverages on the activities:

There have been a very large number of media coverages including electronic and print media. There were several coverages like:

(i) TV reports in Door Darshan and private TV channels,
(ii) Articles by columnists in print and electronic newspapers and magazines
(iii) News in national and regional newspapers
(iv) Articles in book authored by others
(v) Interview by editor in magazine

Some of the media coverages are:

a) Restore our Earth Volume I: Rejuvinating Water, book by Earthday Network
Arsiron Nilogon: Article by Monodip Dutt, Assistant Editor
https://mail.google.com/mail/u/0?ui=2&ik=08bd08bfef&attid=0.1&permmsgid=msg-a:r6534814679101970916&view=att&disp=safe&realattid=178504f9ff5d88309121

b) Outlook
https://www.outlookindia.com/newsscroll/this-lowcost-filter-removes-arsenic-iron-from-water/1576673

c) **The Quint**:
https://www.thequint.com/news/hot-news/in-assam-s-villages-a-low-cost-diy-technology-is-battling-contaminated-water

d) **Mongabay:**
https://india.mongabay.com/2018/03/a-simple-low-cost-filter-that-removes-arsenic-and-iron-from-water/

e) **Business Standard:**
https://www.business-standard.com/article/news-ians/low-cost-technology-together-removes-arsenic-iron-from-water-117031400179_1.html

f) **India Times:**
https://www.indiatimes.com/news/india/rs-500-to-filter-100-000-litres-of-water-researchers-develop-cheap-filter-for-arsenic-content-353669.html

g) **Times of India:**
https://timesofindia.indiatimes.com/blogs/talkingturkey/focus-northeast-projects-like-arsiron-nilogon-can-transform-lives-and-develop-the-region/

h) **Chemical Today Magazine:**
https://www.worldofchemicals.com/media/solving-grassroots-level-problems/2103.html

i) The Thumbprint:
http://www.thethumbprintmag.com/the-peoples-scientist/

j) India Water Portal
https://www.indiawaterportal.org/articles/nilogon-fluoride-removal-groundwater

Some of the news clips are given below:

HINDUSTAN TIMES, NEW DELHI
MONDAY, SEPTEMBER 24, 2018

ARSENIC-FREE DRINKING WATER

Assam researchers make low-cost filter

Utpal Parashar

GUWAHATI: Residents of Margaon village in Assam's Lakhimpur district could do little about the arsenic contaminated water they were forced to drink until a few years back. They found most water purifying machines expensive until they began using a low cost and easy-to-use filter – Arsiron Nilogon.

Researchers at Assam's Tezpur University have developed and patented the filter that removes arsenic and iron from drinking water. It has been making a difference to the lives of thousands of people across the state by providing them access to clean drinking water they did not have until a few years back.

"Six big and small arsenic filters have been set up in our village and nearly 400 people are benefitting from them. Now we are not worried about consuming arsenic with our drinking water," said Deeprupa Bhaktiari, a Margaon-resident

The Union science and technology department has acknowledged the method the filter uses. It has been published in national and international journals and was granted patent number 280737 last year.

High amounts of arsenic, a poisonous contaminant that can cause diseases like cancer, have been detected in Assam's 29 of the 33 districts. The World Health Organisation (WHO) recommends a maximum of 10 ppb (part per billion) of arsenic in drinking water. A Tezpur University research found 960 ppb of the carcinogenic agent in a tubewell in Margaon.

"Concerned about the situation, we began our research in 2005 to find an easy and cheap solution that would benefit poor people in rural areas," said Tezpur University professor Robin Kumar Dutta.

Dutta and his team tried finding a new method as several existing methods of removing arsenic like reverse osmosis were found to be ineffective for use in rural areas of developing countries due to high cost, use of electricity etc.

Dutta said a Japanese firm has approached them for exclusive rights to produce the filter commercially. "But as that would make the method costly and out of reach of poor people, who we want to benefit, we rejected the offer."

• The low-cost filter is able to remove arsenic content. BY ARRANGEMENT

Dutta's team developed the filter in 2010, which involves treatment of contaminated water using small quantities of cooking soda, potassium permanganate and ferric chloride.

The results were impressive. The process was able to remove arsenic content from as high as 1,000 ppb to less than 2 ppb or to the undetectable levels.

"...(The filter) is very effective as, unlike other available methods, it does not use electricity and removes arsenic and other heavy metals at very lost cost," said Manoranjan Nath of Tezpur-based North Eastern Regional Institute of Water and Land Management (NERIWLM).

NERIWLM did the third party technical evaluation of Arsiron Nilogon using various samples of groundwater with high arsenic content (between 500 ppb and 250 ppb). It found the filter was able to bring it down to single digits – below the WHO's recommended levels.

Two 20 litre buckets – one for chemical treatment water and other to be used as a sand gravel filter – are needed to set up a filter unit at home along. A 500-litre unit costs ₹3,700.

For a household unit of 20 litres, one needs to add just 2 gm of cooking soda, nearly 6 drops of potassium permanganate and around 2 ml of ferric chloride. It would cost a user around ₹500 to filter 100,000 litres of water.

"We started taking field trials in 2010. The filter soon became popular and people asked us to set it up for them. Till date, we have set up over 100 filters across Assam, but many more are being set up by users themselves after getting training from us," said Dutta.

A filter unit was set up in Uttar Pradesh's Mirzapur two months ago.

"We have been using the filter to remove arsenic from our drinking water for our family of 24 members. Now many more people in the area want to get such units installed," said Akhilesh Kumar, a school teacher in Mirzapur.

News in Hindustan, New Delhi

राजकाज आज का दिन

1861 में कैलिफोर्निया के जस्टिस ने अमेरिकी राष्ट्रपति लिंकन को पहला अंतरमहाद्वीपीय टेलीग्राफ भेजा।

एक रुपये में 100 लीटर पानी होगा आर्सेनिक मुक्त

हिन्दुस्तान एक्सक्लूसिव

पटना | संजय पांडेय

राज्य के ग्रामीण इलाके में जल्द ही आरओ से भी शुद्ध, पोषक तत्वों से भरपूर सस्ता पानी पीने को मिलेगा। यह पानी आर्सेनिक और लोहा से पूरी तरह मुक्त होगा। आर्सेनिक प्रभावित इलाके में यह पानी एक रुपये में 100 लीटर मिलेगा।

यह संभव होगा असम के तेजपुर विश्वविद्यालय के रसायन शास्त्र के प्रो. रॉबिन कुमार दत्ता के आर्सिरॉन निलोगॉन तकनीक से। प्रो. रॉबिन की इस तकनीक का परीक्षण राज्य के बक्सर जिले के सर्वाधिक आर्सेनिक प्रभावित ब्लॉक सिमरी और ब्रह्मपुर में हो चुका है। परीक्षण के दौरान एनआईटी पटना के विशेषज्ञ प्रो. सुब्रतो दास, स्वस्थ भारत प्रेरक मयंक जोशी, प्रो. दत्ता के सहयोगी सुजॉय चक्रवर्ती आदि मौजूद थे। बक्सर के डीएम राघवेंद्र सिंह की पहल पर पोषण अभियान के तहत प्रो. दत्ता की तकनीक का प्रदर्शन किया गया।

इसमें मौजूद लोगों को पानी से आर्सेनिक और आयरन निकालने के लिए आर्सिरॉन निलोगन तकनीक की जानकारी दी गई। घरों में इस्तेमाल होनेवाले खाने का सोडा, पौटैशियम परमैग्नेट और फेरिक क्लोराइड जैसे सस्ते रसायन का प्रयोग कर पानी को आर्सेनिक मुक्त किया जा सकता है। राष्ट्रीय पोषण मिशन के मयंक जोशी ने बताया कि बक्सर के अलावा आर्सेनिक प्रभावित अन्य जिलों के गांवों में भी इस विधि का प्रयोग होगा।

मिलेगा शुद्ध पानी

- तेजपुर विश्वविद्यालय के प्रो. रॉबिन दत्ता के आर्सिरॉन निलोगॉन तकनीक से मिलेगा शुद्ध पानी
- कैंसर के कारक आर्सेनिक वाले पानी से राज्य के ग्रामीणों को मिलेगी मुक्ति

आर्सिरॉन निलोगॉन तकनीक से साफ होता पानी।

10 – 10 यूनिट तैयार की है जीविकाकर्मियों ने

बक्सर के प्रभावित गांवों में लगेगी यूनिट : डीएम

बक्सर डीएम राघवेंद्र सिंह ने बताया कि शुद्ध पानी उपलब्ध कराने के लिए स्वास्थ्य मंत्रालय से 26 लाख जिले को दिया था। आर्सेनिक मुक्त पानी पर इनोवेटिव आइडिया के लिए जिले को वह पुरस्कार की राशि मिली थी। इस राशि से टाटा शुद्ध जैसे उपकरण खरीद कर कुछ प्रभावित गांवों में बांटे जा सकते थे, लेकिन कुछ नया करने के उद्देश्य से प्रो. रॉबिन दत्ता से संपर्क किया गया। इनकी तकनीक काफी सस्ती और आर्सेनिक को निकालने में प्रभावी है। तीन अक्टूबर को सिमरी और ब्रह्मपुर ब्लॉक में तकनीक का प्रदर्शन किया गया। एनआईटी के प्रोफेसर प्रो. सुब्रतो दास की मदद से जीविकाकर्मियों ने पानी साफ करने की 10-10 यूनिट तैयार की है। इसे आर्सेनिक प्रभावी गांवों में आंगनबाड़ी केंद्रों पर और सामुदायिक भवनों में लगाया जाएगा। इसके रखरखाव के लिए हर आंगनबाड़ी केंद्रों पर मास्टर ट्रेनर भी रखे जाएंगे।

क्या है आर्सिरॉन निलोगॉन : आर्सिरॉन निलोगन पानी से आर्सेनिक व आयरन (लोहा) निकालने का सबसे सस्ता और प्रभावी तकनीक है। इसे प्रो. रॉबिन कुमार दत्ता ने विकसित किया है। इसके लिए उन्हें भारत सरकार से पेटेंट मिल चुका है। यह 1000 पीपीबी जैसे उच्च आर्सेनिक वाले पानी को शुद्ध करके आर्सेनिक की मात्रा 2 पीपीबी से भी कम कर देता है। सस्ती होने के कारण इस तकनीक से ग्रामीण इलाके के गरीब से गरीब व्यक्ति को भी शुद्ध पानी पीने को मिल सकेगा। श्रीश्री रविशंकर समेत कई राष्ट्रीय- अंतरराष्ट्रीय संस्थाएं उनकी सराहना कर चुकी हैं।

News in Hindustan, Patna Edition about implementation of Arsiron Nilogon in Buxar.
https://www.livehindustan.com/bihar/story-100-liters-arsenic-free-water-for-1-rupees-in-bihar-2815369.html

दस रुपये में पानी में दूर होगा आर्सेनिक

अच्छी खबर

कछवां (मिर्जापुर) | सर्वेश सिंह

महज दस रुपये खर्च करके पानी से आर्सेनिक जैसे खतरनाक तत्व को दूर भगाएं और पानी को पीने योग्य बनाएं। यही नहीं दस रुपये में अनचाहे रूप से होने वाली जानलेवा बीमारी कैंसर, नाखून झड़ना, शरीर पर सफेद दाग होने आदि बीमारियों से भी हमेशा-हमेशा के लिए छुट्टी पाएं। वह सुझाव असोम राज्य के तेजपुर विश्वविद्यालय के रसायनशास्त्र विषय के डा. रोबिन दत्ता ने दिए। डा. रोबिन दत्ता क्षेत्र के दमोदरपुर स्थित स्वामी विवेकानंद एकेडमी के प्रधानाचार्य

राहत की बात

- आर्सेनिक से होती हैं कैंसर समेत कई खतरनाक बीमारियां
- तेजपुर विवि में रसायनशास्त्रविद ने किया कारगर उपाय

कई गांवों के पीनी के पानी के स्रोतों हैं डपंप, नलकूप की जांच करने के बाद दी है। राबिन ने यहां के पानी का सूक्ष्म विश्लेषण किया। विश्लेषण में आर्सेनिक की मात्रा डब्ल्यूएचओ के निंधारित मात्रा से अधिक पाया। डब्ल्यूएचओ के अनुसार एक बिलियन लीटर पानी में पीपीबी आर्सेनिक की मात्रा होना चाहिए। लेकिन यहां के पानी में 50 पार्टस प्रति बिलियन लीटर (पीपीबी) मौजूद हैं। जो खतरनाक बिंदू से अधिक है।।

डा. रोबिन डाक्टरिन के अनुसार 20 लीटर पानी में दो ग्राम खाने का

मिर्जापुर के कछवां क्षेत्र में आर्सेनिकमुक्त पानी के साथ विशेषज्ञ।

मैगनेट (लाल दवा), दो-दो मिली लीटर फेरिक क्लोराइड डालकर पानी को खूब मिलाएं। अच्छे से मिलाने के बाद इसे दो घंटे तक छोड़ दें। जब आर्सेनिक बर्तन की तलहटी में जम जाए तो पानी को बर्तन से बाहर निकाल लें।नीचे जमे कचरे को जमीन

फार्मूले को आर्सिरन निलगन विधि के नाम से भी जानते हैं।

इस विधि को डा. रोबिन ने पेटेंट भी कराया है। डा.रोबिन ने एकबार पहले जनवरी में पानी को सैंपलिंग की थी। इस बार ग्रामीणों को पानी साफ करने की विधि बताई। इससे लोगों में

News Published in Hindustan, Mirzapur, UP

This TV reporter prepared the news without our knowledge. There have many more TV reports on Arsiron Nilogon and Fluoride Nilogon.

Please have a view:

https://www.youtube.com/watch?v=qysRVssuSMw

hindustantimes

Tackling pollution to provide clean drinking water for all

SOLUTION Experts are trying to develop new, innovative techniques to treat water contaminated with arsenic and fluoride

Rhythma Kaul
letters@hindustantimes.com

People stand in queues to fill vessels with drinking water in Chennai, which suffered from an acute water shortage caused by drying lakes and depleted groundwater, on June 19, 2019. AP FILE

Not just air, water pollution is also a major concern with most water bodies being used as dumping sites for industrial waste, untreated sewage and even solid waste matter, making water largely unfit for drinking and a health hazard.

Several studies have shown how water pollution remains a global challenge, especially chemical contamination.

A World Bank report, *Quality Unkown: The Invisible Water Crisis*, released in August this year, using a vast database on water quality, showed it would be nearly impossible to meet the global targets set to save the deteriorating environment by 2030. Failure to meet the targets will eventually have an impact on the overall health, economy, education, and so on, of all countries.

The 193 United Nations (UN) member-states agreed on September 25, 2015 to a 15-year target of 17 sustainable development Goals (SDGs), with 169 targets aimed at helping everyone live healthier, more prosperous lives on a cleaner planet.

SDG 6 refers to clean water and sanitation for all, but the UN World Water Development Report found about three out of 10 people - 2.1 billion - did not have access to safely managed drinking water at home in 2015. India was no different, with many parts of the country reporting water contamination due to arsenic, mercury, cadmium and fluoride, among others.

Arsenic contamination, especially is huge, and was first reported in 1983 from West Bengal. Since then, it has affected at least six other Indian states -- Jharkhand, Bihar and Uttar Pradesh, in the floodplains of the Ganga river; Assam and Manipur in the floodplains of the Brahamaputra and Imphal rivers and Rajnandgaon village in Chhattisgarh, according to the abstract, *Groundwater Arsenic Contamination in India: Vulnerability and Scope for Remedy*, prepared by experts from the National Institute of Hydrology, Roorkee.

Some experts say it is a problem in the floodplains of all rivers originating from the Himalayas and the Barail range in the northeast.

Arsenic poisoning leads to symptoms such as skin diseases, liver toxicity, heart ailments, destruction of red blood cells, and even cancer.

TED Talks INDIA नई बात

TACKLING WATER CONTAMINATION

Efforts have been made by various agencies and individual experts in devising ways to ensure safe water supply to the affected population.

Robin Dutta, a professor in the chemical sciences department at Tezpur University in Assam, has been working on a technique to remove arsenic and fluoride from water since 2005, and after five years of work, finally the technique became functional in 2010 and first tested in Assam's Jorhat city, one of the severely affected areas in the state.

The technique was patented in 2017.

"While most other contaminants such as lead, mercury etc. are a man-made problem, arsenic and fluoride contamination is due to natural causes and affects vast areas and larger populations. We developed two methods for removal of arsenic and fluoride that are easy to make and very cheap, which makes it useful at the grassroots level," says Dutta.

The techniques have been named Arsiron Nilogon (for removal of arsenic) and Fluoride Nilogon (for fluoride removal).

"Arsiron Nilogan is a technique wherein we create a condition that's similar to underground water that doesn't have arsenic by making use of catalysts such as cooking soda, potassium permanganate and ferric (iron) chloride. These are all commonly available chemicals. As a result of the chemical process that takes place by mixing these compounds together, arsenic settles on coagulated ferric chloride and can be removed through filtration technique," says Dutta.

The basic idea behind the technique was to convert a difficult-to-remove form of arsenic to an easy-to-remove form. The cost of using the technique is as low as 1 paisa for filtering one litre of water.

The Fluoride Nilogon technique involved treating water with crushed limestone that absorbs fluoride and phosphoric acid. The contaminant in this case can also be filtered out. The cost is even lower than the arsenic removal technique at 0.4 paise to filter a litre of water.

With support from the department of science and technology for his project, Dutta is already working on expanding the technique to other states such as Bihar and Uttar Pradesh that are also grappling with water contamination.

Dr Kuttanellore Muraleedharan, director of the Council of Scientific and Industrial Research (CSIR)-Central Glass & Ceramic Research Institute (CGCRI), has also worked on filtration techniques that help remove hazardous contaminants from water.

"Be it arsenic, iron or other elements dissolved in water, our ceramic membrane technology is capable of purifying it with good results," he says.

CGCRI experts developed the technology over a decade ago but it picked up only about 5-6 years ago. A filtration plant can be installed at the community level to filter water for as low as 20 paise per litre.

"It can purify everything else apart from the saline contamination for which reverse osmosis (RO) technique is good enough. There have to be slight modifications done before installation based on the type of contaminant in water. The device can stay active for 6-7 years," said Dr Swachchha Majumdar, a researcher at the CGCRI lab who is also part of the team that developed the technology.

The institute has tied up with a manufacturer and takes orders for installation of the plant at its laboratory. "It is our indigenous product and our laboratory takes the orders," he added.

Dr Muraleedharan says, "There is a huge need to come up with innovative techniques for water purification that are affordable for masses at the ground level as water contamination is a major issue in India."

Hindustan Times: Sunday feature

দৈনিক অসম
গুৱাহাটী আৰু ডিব্রুগড়ৰ পৰা প্ৰকাশিত
শেহতীয়া স
২ ছলমানক ভাবুকি
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■ ৫৫ বছৰ ■ ৫২ সংখ্যা, ৮ আহিন, বৃহস্পতিবাৰ, ১৯৪১ শক ■ DAINIK ASAM : Assamese Daily ■ VOL. 55 NO. 52 ■ GUWAHATI, THURSDAY, SEPTEMBER 26, 2019 ■ পৃষ্ঠা ১২

অসমীয়া বিজ্ঞানীৰ উদ্ভাৱনে আদৰ পাইছে চত্তিছগড়-ওড়িশাত

নতুন পদ্ধতিৰে ফ্লু'ৰাইডমুক্ত কৰা হ'ব কার্বি আংলঙৰ পানী

নিজা বাতৰি দিওঁতা

বকলীয়াঘাট, ২৫ ছেপ্টেম্বৰ ঃ কার্বি আংলং জিলাৰ বিভিন্ন স্থানত খোৱাপানীত মাৰাত্মক ফ্লু'ৰাইডৰ উপস্থিতি এক বৃহৎ সমস্যা হিচাপে বিবেচিত হৈ আহিছে। হোজাই-কার্বি আংলং জিলাৰ সীমামুৰীয়া এক বৃহৎ এলেকাত খোৱাপানীত অধিক পৰিমাণৰ ফ্লু'ৰাইডৰ উপস্থিতিৰ বাবে দশকৰ পিছত দশক ধৰি সীমাহীন দুর্ভোগ ভুগি আহিছে এইসকল লোকে। ফ্লু'ৰাইড আৰু আর্ছেনিকযুক্ত পানী সেৱন কৰাৰ ফলত এইসকল লোকে দাঁত আৰু হাড়ৰ ৰোগত আক্রান্ত হৈ অকাল বার্দ্ধক্যক আদৰি ল'ৰলগীয়া পৰিস্থিতিৰো সৃষ্টি হৈছে। ইয়াৰ বিপৰীতে অসম চৰকাৰৰ জনস্বাস্থ্য কাৰিকৰী বিভাগে বিগত সময়ছোৱাত ফ্লু'ৰাইড আক্রান্ত এলেকাসমূহত বসবাস কৰি থকা লোকসকলক ফ্লু'ৰাইডমুক্ত বিশুদ্ধ খোৱাপানী যোগান ধৰাৰ ক্ষেত্রতো চূড়ান্তভাবে *৯ পৃষ্ঠাত চাওক*

নতুন পদ্ধতিৰে ফ্লু'ৰাইডমুক্ত কৰা হ'ব

বিফল হোৱাৰ অভিযোগ বিভিন্ন সময়ত উত্থাপিত হৈ আহিছে। এলেকাটোৰ ডকমকা, টেকেলাংজুন, হালধিআটী, চামেলাংছু' আদিত খোৱাপানীত প্রচুৰ পৰিমাণে মিহলি হৈ থকা ফ্লু'ৰাইডৰ সমস্যাৰ বাবে কম বয়সতে ৰুগীয়া জীৱন কটাবলগীয়া হৈছে শ শ লোকে। চৰকাৰৰ এটা বিয়াগোম বিভাগে ব্যর্থতা প্রদর্শন কৰি অহাৰ বিপৰীতে তেজপুৰ বিশ্ববিদ্যালয়ৰ এগৰাকী অধ্যাপকে শেহতীয়াকৈ উদ্ভাৱন কৰা এক পদ্ধতি এইক্ষেত্রত বিশেষ ফলপ্রসূ হিচাপে পৰিগণিত হৈছে। যোৱা কেইবাটাও বছৰ ধৰি আক্রান্ত এলেকাসমূহত খোৱাপানী ফ্লু'ৰাইডমুক্ত কৰাৰ বাবে আহোপুৰুষার্থ কৰি আহিছে তেজপুৰ বিশ্ববিদ্যালয়ৰ ডঃ ৰবীন কুমাৰ দত্তই। ১৯৯৭ চনতে কার্বি আংলং জিলাত হোৱা ফ্লু'ৰাইডৰ ভয়াৱহতা প্রত্যক্ষ কৰি এই গবেষণাৰ কাম আৰম্ভ কৰিছিল অধ্যাপকগৰাকীয়ে। ২০১৩ চনৰপৰা জিলাখনৰ ডকমকা এলেকাত এই পদ্ধতি অৱলম্বন কৰি অধ্যাপকগৰাকীয়ে সুফল লাভ কৰিছে। যোৱা কেইটামান বছৰত এলেকাটোত ফ্লু'ৰাইড আক্রান্ত হোৱা লোকৰ সংখ্যা লক্ষণীয় হাৰত হ্রাস পোৱাৰ বিপৰীতে এই পদ্ধতি হৈছে নিতান্তই কম খৰচী। চূণশিলৰ লগত পটেছিয়াম দি পানী শোধন কৰা হয় এই প্রক্রিয়াত। অধ্যাপকগৰাকীৰ এই পদ্ধতিৰে ইতিমধ্যে চত্তিছগড় আৰু ওড়িশাত এটা আন্তঃৰাষ্ট্রীয় স্বেচ্ছাসেৱী সংগঠনে পানী শোধনৰ প্রক্রিয়া আৰম্ভ কৰিছে। ইয়াৰ পিছতে শেহতীয়াকৈ অধ্যাপকগৰাকীৰ এই পদ্ধতি প্রয়োগ কৰি পাহাৰীয়া জিলাখনৰ ফ্লু'ৰাইড আক্রান্ত এলেকাত খোৱাপানী ফ্লু'ৰাইডমুক্ত কৰাৰ বাবে আগবাঢ়ি আহিছে কার্বি আংলং স্বায়ত্ত শাসিত পৰিষদ। আর্ট অৱ লিভিঙৰ ডিফু কার্যালয়ত কালি এই আঁচনিখনৰ শুভ উদ্বোধন কৰে ডিফুৰ সাংসদ হৰেনছিং বেই। কার্বি আংলং স্বায়ত্ত শাসিত পৰিষদৰ সহযোগত জিলাখনৰ ১৬ হাজাৰ পৰিয়ালৰ ঘৰত এই পদ্ধতিৰে পানী ফ্লু'ৰাইডমুক্ত কৰিব আর্ট অব্ লিভিঙে। আর্ট অব্ লিভিঙৰ কর্মকর্তা বিষ্ণুৰে আঁত ধৰা এই অনুষ্ঠানত অংশগ্রহণ কৰি প্রদান কৰা ভাষণত কার্বি আংলং স্বায়ত্ত শাসিত পৰিষদৰ কার্যবাহী সদস্য প্রদীপ বংহাঙে এই পদ্ধতি সমগ্র কার্বি আংলং জিলাতে প্রয়োগ কৰা হ'ব বুলি ঘোষণা কৰে। অধ্যাপক দত্তক ফ্লু'ৰাইড আক্রান্ত এলেকাৰ লোকসকলৰ বাবে দেৱদূত বুলি অভিহিত কৰে সাংসদ হৰেনছিং বেই। আনহাতে, অধ্যাপক দত্তই উক্ত সভাতে কম খৰচত বাহিজে খোৱাপানী ফ্লু'ৰাইড আৰু আর্ছেনিকমুক্ত কৰি তোলাৰ পদ্ধতিৰ বিস্তৃত ব্যাখ্যা আগবঢ়ায়। অধ্যাপকগৰাকীয়ে লগতে এই পদ্ধতিয়ে আন্তঃৰাষ্ট্রীয় জার্ণেলতো স্বীকৃতি লাভ কৰা বুলি উল্লেখ কৰে। উক্ত অনুষ্ঠানৰ সৈতে সংগতি ৰাখি এক বৃক্ষৰোপণ কার্যসূচীও ৰূপায়ণ কৰা হয়।

দৈনিক জনমভূমি

নিভীক সাংবাদিকতাৰ প্ৰতীক

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September 25, 2019

চলা সন্ত্রাসবাদ

কার্বি আংলঙৰ ফ্লু'ৰাইড আক্রান্ত এলেকাত আৰ্ট অব্ লিভিঙৰ পদক্ষেপ

নতুন পদ্ধতিৰে পানী বিশুদ্ধকৰণ আৰম্ভ

ডিফু ঃ ষ্টাফ বিপৰ্টাৰ, ২৪ ছেপ্টেম্বৰ ঃ ৰাজ্যৰ ২৩খন জিলাৰ বিভিন্ন এলেকাৰ জনতাই দীৰ্ঘদিন ধৰি ফ্লুৰাইড আৰু আৰ্ছেনিকযুক্ত পানী সেৱন কৰি আহিছে। যাৰ ফলত বহু লোক দাঁতৰ অসুখ, হাড়ৰ অসুখত ভুগি অকালতে বৃদ্ধ হ'বলগা হৈছে। আৰ্ছেনিক আৰু ফ্লুৰাইডমুক্ত পানী জনতাক দিয়াৰ বাবে অসম চৰকাৰৰ জনস্বাস্থ্য কাৰিকৰী বিভাগ বিফল হৈছে। কার্বি আংলং জিলাৰো ডকমকা, টেকেলাংজুন, হালধিআটী, ছামেলাংছ' আদি এলেকাৰ পানীত প্ৰচুৰ পৰিমাণে ফ্লুৰাইড আছে। যাৰ ফলত উক্ত এলেকাৰ বহু লোক অকালতে বৃদ্ধ হৈছে। বৰ্তমান উক্ত এলেকাত নতুনকৈ কোনো লোক ফ্লুৰাইডযুক্ত পানী সেৱনৰ ফলত দাঁত বা হাড়ৰ বোগত আক্রান্ত হোৱা নাই যদিও এতিয়াও কিন্তু উক্ত এলেকাৰ লোকসকল বিপদমুক্ত নহয়। আৰ্ছেনিক আৰু ফ্লুৰাইডযুক্ত পানী শোধন কৰাৰ বাবে তেজপুৰ বিশ্ববিদ্যালয়ৰ অধ্যাপক ড° ৰবীন কুমাৰ দত্তই অতি কম খৰচৰ এক পদ্ধতি উদ্ভাবন কৰিছে। ১৯৯৭ চনত কার্বি আংলং জিলাত হোৱা ফ্লুৰাইডৰ ভয়াবহতা দেখি তেওঁ এই গৱেষণা আৰম্ভ কৰিছিল। ২০১৩ চনৰ পৰা তেওঁ কার্বি আংলং জিলাৰ ডকমকা এলেকাত এই পদ্ধতি অবলম্বন কৰি সফলতা লাভ কৰিছে। চুণশিলৰ লগত পটাচিয়াম দি পানী শোধন কৰা এই পদ্ধতিত মাহে মাত্ৰ ৪ পইচা খৰচ পৰে। অধ্যাপকগৰাকীৰ এই পদ্ধতিৰে ইতিমধ্যে ছত্তিশগড় আৰু ওড়িষাত এটা আন্তঃৰাষ্ট্ৰীয় স্বেচ্ছাসেৱী সংগঠনে পানী শোধন আৰম্ভ কৰিছে। কার্বি আংলং জিলাৰ পানীত থকা ফ্লুৰাইড শোধনৰ বাবে স্বায়ত্তশাসিত পৰিষদে অধ্যাপক দত্তৰ পদ্ধতি প্ৰয়োগ কৰিবলৈ আগবাঢ়িছে। আৰ্ট অব্ লিভিঙৰ ডিফু কার্যালয়ত আজি এই আঁচনিৰ আনুষ্ঠানিক শুভাৰম্ভ কৰে সাংসদ হৰেনছিং বে'য়ৈ। কার্বি আংলং স্বায়ত্তশাসিত পৰিষদৰ সহযোগত আৰ্ট অব্ লিভিঙে বৰ্তমান ১৬ হাজাৰ পৰিয়ালৰ ঘৰত এই পদ্ধতিৰে পানী শোধন কৰিব। আৰ্ট অব্ লিভিঙৰ কৰ্মকৰ্তা বিষ্ণুয়ে আঁত ধৰা অনুষ্ঠানটোত জনস্বাস্থ্য কাৰিকৰী বিভাগৰ কার্যবাহী সদস্য প্ৰদীপ ৰংপিয়ে কয় যে এই পদ্ধতি সমগ্ৰ কার্বি আংলং জিলাত প্ৰয়োগ কৰা হ'ব। বৰ্তমান যিসমূহ এলেকাৰ পানীত ফ্লুৰাইড আছে, সেই এলেকাত এই পদ্ধতিৰে পানী শোধন কৰা হ'ব। পৰ্যায়ক্ৰমে সমগ্ৰ জিলাত এই পদ্ধতি প্ৰয়োগ কৰাৰ পোষকতা কৰে তেওঁ। সাংসদ হৰেনছিং বে'য়ে অধ্যাপক দত্তক তেওঁ কার্বি আংলং জিলাৰ ফ্লুৰাইড আক্রান্ত এলেকাৰ দেৱদূত আখ্যা দিয়ে। অধ্যাপক দত্তই অতি কম খৰচত ৰাইজে আৰ্ছেনিক আৰু ফ্লুৰাইডমুক্ত পানী খাব পৰা পদ্ধতিটোৰ ব্যাখ্যা কৰে। তেওঁৰ এই পদ্ধতিক আন্তঃৰাষ্ট্ৰীয় জার্নেলত স্বীকৃতি লাভ কৰা বুলি কয়। আৰ্ট অব্ লিভিঙৰ সমূহ কর্মকৰ্তা উপস্থিত থকা অনুষ্ঠানত বৃক্ষৰোপণো কৰা হয়।

ছলাংদ
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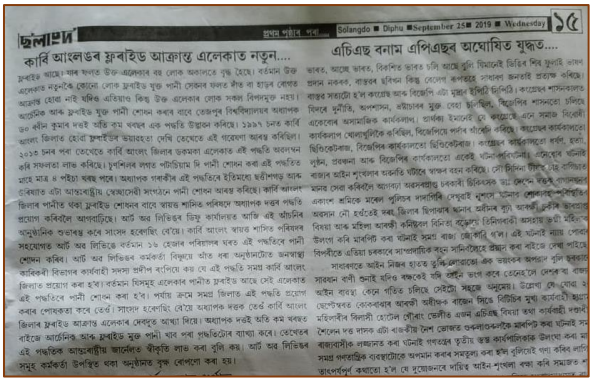
কার্বি আংলঙৰ ফ্লুৰাইড আক্রান্ত এলেকাত নতুন পদ্ধতিৰে পানী বিশুদ্ধিকৰণ আৰম্ভ

স্বায়ত্ত শাসিত পৰিষদৰ সহযোগত আৰ্ট অব লিভিঙৰ ইতিবাচক পদক্ষেপ



ছলাংদ
Solangdo ■ Diphu ■ September 25■ 2019 ■ Wednesday

কার্বি আংলঙৰ ফ্লুৰাইড আক্রান্ত এলেকাত নতুন....

এচিএছ বনাম এপিএছুৰ অঘোষিত যুদ্ধত....

THE HILLS TIMES
Voice of the hills people

PHED setting up a 40,000 litre fluoride treatment plant at Rongkangthir Village

Karbi Anglong set to get fluoride contaminated free drinking water

दैनिक अकेला
Dainik 'Akela', Tinsukia, 12 January 2020

तस्करी कर बांग्लादेश भेजे | भारी मात्रा में डूम्स

साफाखाटी में 'आर्सिन निलगन' तकनिक सम्बन्धि कार्यशाला

साफाखाटी,11 जनवरी (दै.अ.)। पीने की पानी से कम खर्च में एक साथ आर्सेनिक और आइरन निकालने की पद्धति 'आर्सिरन निलगन' तकनिक के प्रयोग के सन्दर्भ में गत 8 जनवरी को साफाखाटी के बारेगांव मध्य अंग्रेजी विद्यालय प्रांगण में एक सजगत सभा एवं प्रशिक्षण कार्यशाला का आयोजन किया गया। उक्त कार्यशाला में तेजपुर केन्द्रीय विश्वविद्यालय के वरिष्ठ अध्यापक तथा विशिष्ठ वैज्ञानिक डा. राबीन कुमार दत्त, तकनीकि विशेषज्ञ -पत्रकार प्रसेनजित राजखोवा उपस्थित थे। डा.दत्त के अनुसार चराईदेव जिला और शिवसागर जिला, अरुणाचल-नागालैंड के सीमावर्ती क्षेत्र सहित दिसांग नदी के दक्षिण ओर भू-गर्भ के जल में आर्सेनिक होने की अधिक सम्भावना है। गौरतलब हो कि विगत वर्ष साफाखाटी के बालीखेतिया गांव के चापा कल से पानी संग्रहकर तेजपुर केन्द्रीय विश्वविद्यालय के रसायन विभाग में उन्नत तकनिक से परीक्षण कर 15 पी बी वी पाया था। जो कि जनस्वास्थ के लिए हानीकारक है। डा. दत्त ने आर्सेनिक के कारण जनस्वास्थ पर क्या-क्या कू-प्रभाव पर सकता है, उसकी विस्तृत जानकरी दी। 'आर्सिरन निलगन' के तकनिकी विशेषज्ञ तथा पत्रकार प्रसेनजित राजखोवा ने मुख्य सतिधि के रुप में पानी से खतरनाक अदृश्य प्रदूषक आर्सेनिक और आईरन निकालने की आसान तरिके की जानकारी दी।

भारतीय म... पर विश्...

चेन्नई। कांग्रेस के वरिष्ठ ... पी चिदंबरम ने कहा कि उन... भारतीयों जैसे भोले-भाले ... कहीं नहीं देखे, जो सरकार ... उसके कार्यक्रमों के क्रियान्व... को लेकर किये गए दावों ... विश्वास कर लेते हैं। पूर्व केन्... मंत्री चिदंबरम ने एक साहित्... कार्यक्रम को संबोधित करते ... कहा कि मैंने भारतीयों जैसे मा... लोग कभी नहीं देखे। ... समाचार पत्रों में कुछ छप जात... (और उन्होंने दो अखबारों के ... भी लिये) तो हम उस पर विश्... कर लेते हैं। उन्होंने कहा कि ... कि इन दावों पर यकीन किया ... कि देश के सभी गांवों में बिज... पहुंच गई है और भारत के ... प्रतिशत परिवारों के ...

ईरानी से...

Arsiron Nilogon

Arsiron Nilogon

Arsenic is a deadly poisonous water contaminant. It is difficult to detect as it is colourless, odourless and has no sedimentation. It is present in groundwater in certain parts of the world, including Assam. The contaminant affects enzymes that control many biological processes in the human body. The intake of untreated water laced with arsenic can over time lead to chronic poisoning and diseases such as skin problems, bronchitis, diabetes, bone marrow depression and cardiovascular disorders. Arsenic is known to be carcinogenic—it can cause cancer in tissues and organs when ingested repeatedly.

While it is advisable to remove all arsenic from drinking water, the WHO sets a maximum permissible level of 10 ppb (10 micrograms per litre). In many districts of the Brahmaputra and Barak river valleys of Assam, groundwater is found contaminated with arsenic far above this level. For the rural populations, arsenic removal techniques such as ion-exchange, Reverse Osmosis, ultrafiltration, and adsorption are unsuitable because of their high costs, the requirement of power, and the limited facilities available for disposal of the large quantities of sludge produced.

In the Chemical Sciences Department of Tezpur University's laboratories in Assam, Professor Robin Kumar Dutta and his students developed an efficient, Do-It-Yourself, low-cost method to remove arsenic, iron and other heavy metal contaminants from groundwater. He says that his research's biggest motivator was great personal loss: he lost his father, brother, uncles and a friend to cancer. Testing the water in his river island village, Majuli, confirmed arsenic presence to be far above permissible limits!

Professor Dutta named the method he developed 'Arsiron Nilogon' as this removes both arsenic and iron simultaneously. In Assamese, 'Arsiron' stands for arsenic and iron, and 'Nilogon,' removal. Arsiron Nilogon removes arsenic from groundwater from any initial concentration to less than 2 ppb or undetectable levels for any water quantity, be it 20 litres or 200,000 litres. The method is simple and easy to assemble at home by a layperson. It is useful for both household and community purposes. The simplicity of the Arsiron Nilogon process doesn't take away from its efficiency. This enabled Professor Dutta to easily transfer the technique from his sophisticated laboratory to the populace.

Arsiron Nilogon is based on oxidation coagulation-adsorption at optimised pH. There is no requirement for any energy to operate it. All it needs is just two buckets that act as filters. These are fitted with taps at different levels. The water is treated with small quantities of common and safe chemicals: cooking soda ($NaHCO_3$), potassium permanganate ($KMnO_4$), and ferric chloride ($FeCl_3$). These help in various ways to remove arsenic and iron. The doses of chemicals in the method differ and depend on whether iron is also present in the water along with the arsenic. The cooking soda controls the water's pH to render it to optimum conditions for the precipitation of iron, should this also be present. At lower pH, iron precipitation is slow, whereas at higher pH, some soluble iron remains in the water. Potassium permanganate oxidises difficult-to-remove arsenite ions to easy-to-remove arsenate ions. This popular oxidising agent for water treatment use has other advantages over its competitors: it exists as a stable solid with high water solubility and forms highly insoluble manganese dioxide at mild alkaline conditions, leaving no manganese or any other residue in the treated water. The manganese dioxide speeds up otherwise very slow arsenite to arsenate conversion and absorbs arsenate ions from water. The mild disinfectant potassium permanganate kills the bacteria present in the water. Ferric chloride is more efficient than alum as a coagulant. It leaves no residual toxic substance in the water, unlike alum, which leaves aluminum ions suspected of causing Alzheimer's disease. The coagulates absorb and remove arsenic

Article by Monodip Dutt, Asstt Ed., in Restore Our Earth Volume I: Rejuvinating Water, p.8-10

Notable Appreciation about Arsiron Nilogon and Fluoride Nilogon:

a) **Prime Minister Mr. Narendra Modi** at TU convocation, Jan 2021 hailed Arsiron Nilogon and Fluoride Nilogon reaching various states in the country.

https://ar-ar.facebook.com/1923353871304344/videos/its-good-to-hear-the-pm-speaking-about-our-arsiron-nilogon-and-fluoride-nilogon-/2821367824851455/

b) **UNICEF Country Representative Dr Yasmin Ali Ahmed and UNICEF Assam Chief of Field Dr. Tushar Rane** visited our laboratory, and Arsiron Nilogon and Fluoride Nilogon demo filters at Tezpur University on 21st August 2019

c) **Members of Task Force of JJM** visited TU to meet the PI to learn about Arsiron Nilogon and Fluoride Nilogon, Mar 2020

d) **Shri Ravi Sankar, Founder of Art of Living tweets twice** on Arsiron Nilogon and Fluoride Nilogon which received maximum retweets.

e) Noted Scientist, **Prof. Gautam R. Desiraju** inquired the detail of Arsiron Nilogon and Fluoride Nilogon from the PI at TU and posted in Facebook about the technologies.

3. Scientific Description of the Product/Process. Give Specifications/ Standards for the same.

(a) Arsiron Nilogon Method:

Arsiron Nilogon is a simple but at the same time one of the most efficient and low-cost method for removal of arsenic from contaminated water suitable for poor rural application. It can remove arsenic from groundwater from any initial concentration to less than 2 ppb or to undetectable level.

The method can remove both arsenic and iron simultaneously, hence the name - Arsiron Nilogon, where, '*Arsiron'* stands for '***Arsenic*** and ***iron***, and '*Nilogon'* means removal.

Arsiron Nilogon is one of seven successful methods developed under initiatives of the DST, New Delhi which have been included in Arsenic Compendium published by the DST (http://dst.gov.in/Arsenic_Compendium.pdf) and also put forward by the Parliamentary Committee for Estimates to the 12th Lok Sabha in Dec., 2015 (http://wrmin.nic.inwritereaddata/16 Estimates on asenic.pdf).

In Arsiron Nilogon, the water is treated with small quantities of three common and safe chemicals:

(i) Cooking soda (also called baking soda but not baking powder, which is different)
(ii) Potassium permanganate and
(iii) Ferric chloride

in a sequence to remove arsenic through oxidation-coagulation-adsorption at optimised pH in batch mode.

The doses of the chemicals in Arsiron Nilogon in weight per liter are shown in Table 1:

Table 3.a.i. The doses of the chemicals in Arsiron Nilogon in terms of weight per liter of water

Chemical	Dose	Form of the chemical
Baking soda ($NaHCO_3$)	0.1 gram per litre	White powder or solution in water
Potassium permanganate* ($KMnO_4$)	0.5 milligram per litre*	5% solution in water (weight/volume)
Ferric chloride ($FeCl_3$)	25 milligram per litre	25% or 40% solution in water (weight/volume)

*More potassium permanganate should be added if the arsenic concentration is above 300 ppb or if iron is also present in the water.

The method can be used from household purpose to large community purpose. Arsiron Nilogon can be used for arsenic removal from any quantity of water, for example, in small household (20 litre) unit, large household and small community (200-1000 litre) unit or large community water supply schemes of up to lakhs of litres per day. A household unit requires

only two buckets or two plastic drums, one for chemical treatment and another as a sand-gravel filter. For large scale community, it requires a plastic or an RCC treatment chamber and a sand-gravel filter.

Arsiron Nilogon Method in Detail:

Arsiron Nilogon can be used for any quantity of water, be it 20 litre or 2,00,000 litres. So, it can be used for both household and community purposes. Arsiron Nilogon can be used for water free from iron and for water with dissolved iron. The doses of chemicals in the method differ if iron is also present in the water along with arsenic.

For household use, it is better to remove iron first, if iron is also present, through sand-gravel filtration before removing arsenic by Arsiron Nilogon to get better results and to reduce cost. A part of the arsenic is also removed during removal of iron.

Arsenic and iron usually occur together in most of the places in Assam except a village in Titabor in Jorhat. Actually, the presence of arsenic and iron in groundwater depends on some properties of the aquifers, the sandy layers where groundwater resides, like reduction potential (Eh) and pH.

For community use, it is better to remove both arsenic and iron together through Arsiron Nilogon. For this, the cost can be reduced by utilizing the iron present in the water for aiding the arsenic removal if one knows the concentration of iron present in the water.

The doses of the chemicals used in Arsiron Nilogon do not change with concentration of arsenic usually present in the water because arsenic present in water is usually much less compared to iron and both arsenic and iron are oxidised by potassium permanganate during Arsiron Nilogon.

Fig. 3.a.i A kit containing the three chemicals needed for Arsiron Nilogon

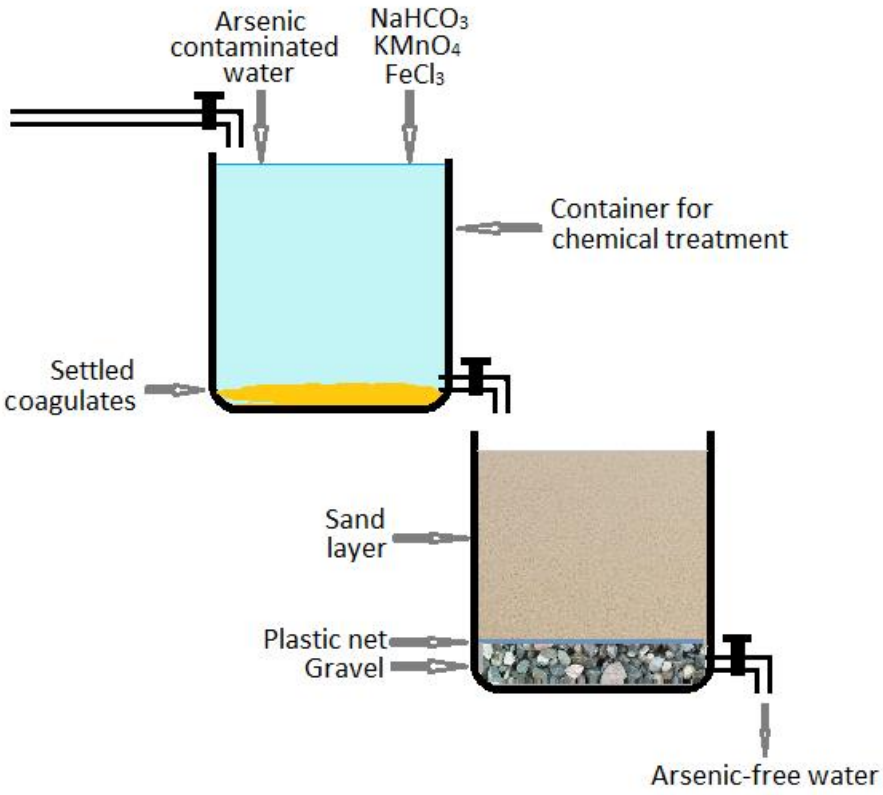


Fig.3.a.ii. A Schematic Diagram of Arsiron Nilogon filter

Specifications*:* For 20 litre household unit made with plastic buckets, at least 10-inch-thick fine to medium size sand layer should be used. Two-inch-thick gravel layer is enough. The taps should be fixed one inch above the bottom. A thin piece of plastic net or synthetic cloth should be spread well between the sand and gravel layer to stop the sand from squeezing into the gravels.

Brown sedimentation of the coagulations can be seen at the bottom of the coagulation chamber. The brown coagulations mainly consist of ferrihydrite (FeOOH). Anionic monohydrogen arsenate, $HAsO^{2-}$, gets adsorbed to the positively charged coagulations and settles down in one to two hours depending upon the depth of water.

If the water also contains high concentration of dissolved ferrous (Fe^{2+}) ions or manganous (Mn^{2+}) ions then large amount of black insoluble MnO_2 produced during oxidation by potassium permanganate. The sediment color will be darker depending upon the amount of MnO_2 produced.

Household Arsiron Nilogon filter *(20-40 litre)*

A household Arsiron Nilogon filter can be made of two plastic buckets or any other water containers of convenient shape. The tap of the upper bucket should be fixed at about one inch above the bottom of the bucket so that there is space for the sediment of coagulations to deposit and remain there. The stand can be custom designed to place the filter below the tap of the coagulation bucket.

Care should be taken so that the tap of the sand-gravel filter is not blocked by gravels. One can place a flat piece of gravel or plastic or ceramic in front of the inner mouth of this tap to ensure free flow of water. The sand and gravels should be thoroughly washed.

Small community filters:
A small community unit for use in schools or other public places may be made using a plastic drum or RCC tank of any required capacity (say 200 litre or larger) for chemical treatment and a 200 tank as sand-gravel filter. Some people have been using 500 litre containers for the chemical treatment. This is in fact good because arsenic-containing water should be avoided in any household use of water including bathing and washing as arsenic is absorbed through skin.

Arsiron Nilogon for water in absence of coexisting iron:
The method involves addition of the three common chemicals to the water to be treated, which takes about three minutes, followed by filtration after one hour of residence time. The three chemicals are added to a certain quantity of arsenic-containing water in a bucket or any other plastic or RCC container in the three steps in a sequence as mentioned below using the recommended doses as shown in Table 3.b below if the water does not contain dissolved iron:

Step 1: Addition of a specified quantity baking soda (not baking powder!).
Step 2: Addition of a specified quantity of potassium permanganate to the water.
Step 3: Addition of a specified quantity of ferric chloride to the water.

Care should be taken for thorough mixing of the chemicals after addition of them in each step. All three chemicals dissolve easily in water. Coagulation, in the form of reddish-brown particles, will be visible within minutes after addition of the chemicals. The water is then allowed to settle for at least an hour. Then the water is filtered through any filter, e.g., a sand-gravel filter to get arsenic-free water.

The required doses of the chemicals are shown in the following tables. Slight variation in the doses won't cause any problem.

Table 3.a.ii. Dose of baking soda for household or small community Arsiron Nilogon units for arsenic removal from water when there is no co-existing iron in the water

Quantity of water	Form of baking soda	Quantity of baking soda*
20 litres	Powder	2 grams
40 litres	Powder	4 grams
200 litres	Powder	20 grams
500 litres	Powder	50 grams

Table 3.a.iii. Dose of potassium permanganate for household or small community Arsiron Nilogon units for arsenic removal from water when there is no co-existing iron in the water

Quantity of water	Strength of potassium permanganate solution in water (weight/volume)	Volume of potassium permanganate solution
20 litre	5%	0.2 ml (approximately 6 drops)
40 litre	5%	0.4 ml (approximately 6 drops)
200 litre	5%	2 ml
500 litre	5%	5 ml

It may be noted that that the colour of potassium permanganate does not remain in the water. If it appears then use a smaller dose of potassium permanganate.

Table 3.a.iv. Doses of ferric chloride for household or small community Arsiron Nilogon units for arsenic removal from water when there is no co-existing iron in the water

Quantity of water	Strength of ferric chloride solution in water (weight/volume)	Volume of ferric chloride solution*
20 litres	25%	2 ml
40 litres	25%	4 ml
200 litres	25%	20 ml
	40%	12.5 ml
500 litres	25%	50 ml
	40%	31.25 ml

Arsiron Nilogon for water in presence of coexisting iron:

Iron is usually present along with arsenic. In presence of such coexisting iron, the doses of the chemicals in Arsiron Nilogon may be different from those in absence of coexisting iron. There are two options for Arsiron Nilogon for water containing dissolved iron:

(i) First remove the dissolved iron by simple sand-gravel filtration and then use Arsiron Nilogon as prescribed for water not containing iron.
(ii) Remove both arsenic and iron together with a modified dose of the chemicals.

For household purpose, it may be better to remove the coexisting iron from water by using a sand-gravel filter and then to remove arsenic by Arsiron Nilogon method. Arsenic is also removed to some extent (about 50%) during iron removal by sand-gravel filter. The water with partially removed arsenic after sand-gravel filtration may be used for some household purposes like washing clothes, cleaning house, etc., if the arsenic level in the water is low. The water after removal of arsenic by Arsiron Nilogon should be used for drinking, cooking, cleaning of food materials like vegetables, rice, pulse, fish, meat, etc.

If Arsiron Nilogon is done after iron-removal, then the required dose of potassium permanganate is low (6 drops for 20 litre water) and therefore the cost of Arsiron Nilogon is low. The Arsiron Nilogon method is also simple and efficient in absence of coexisting iron.

In case of small community purpose, it may not be convenient to remove iron separately before doing arsenic removal and therefore it is better to remove both coexisting iron and arsenic together by Arsiron Nilogon. In this case, the following instructions should be followed:

Step 1: Add baking soda (not baking powder!) equal to the amount added in absence of coexisting iron. In presence of coexisting iron, the dose of baking soda usually remains same as that in absence of coexisting iron.

Step 2: Go on adding 5% potassium permanganate solution, above the amount required for absence of coexisting iron, until a purple color of potassium permanganate continues to disappear. Note down this dose of potassium permanganate.

The dose of potassium permanganate can be lowered by proper aeration of the water by using a shower in the inlet of water. This allows absorption of more oxygen from air to oxidize the coexisting iron.

In case of large community water supply units, similar adjustment of the potassium permanganate dose may be done with proper aeration of the water.

Step 3: For low concentrations of coexisting iron, the dose of ferric chloride may be same as that in absence of coexisting iron.

However, for water containing high concentration of coexisting iron we can reduce the dose of 25% ferric chloride by 0.2 ml for every ppm of coexisting iron in 20 litres of water to be treated. Thus, one does not need to add ferric chloride if the concentration of coexisting iron is 10 ppm or higher. For this, one must know the concentration of the coexisting iron in the water.

Thus, with proper aeration and determination of the concentration of coexisting iron, the additional cost due to increase in the dose of potassium permanganate can be reduced to some extent if one intends to remove both arsenic and iron simultaneously by Arsiron Nilogon.

For large community water supply units, the doses of sodium bicarbonate, potassium permanganate and ferric chloride can be adjusted to make use of the dissolved iron for partial or complete replacement of ferric chloride to reduce the cost. For this the exact iron concentration in the water should be known.

Table 3.a.v. A summary Table of doses for 20 liter* of water:

Groundwater type	Cooking soda	5% (w/V) Potassium permanganate	25% (w/V) Ferric chloride
Having no iron	2gram	0.2ml or 6 drops	2 ml
Having iron#	2gram	less than that gives a light purple color to the water#	2 ml#

***Increase the doses proportionately for larger quantity of water. Slight variation in doses does not matter.*

#*Iron can be removed along with arsenic. For water containing iron, add more potassium permanganate as long as the color of potassium permanganate continues to disappear. The dose of 25% ferric chloride can be reduced by 1 ml for each 3.5 ml of 5% potassium permanganate if the water contains excess iron.*

The chemical tricks applied in Arsiron Nilogon:

The three chemicals used in the present method helps in various ways in removal of arsenic and iron making the method highly efficient and safe:

(i) $NaHCO_3$ controls the pH of the water in an optimum range in which $KMnO_4$ and $FeCl_3$ work most efficiently and as desired. Arsenate ions are removed more efficiently in the pH range provided by $NaHCO_3$ than at pH higher or lower than that. Arsenate adsorption decreases in more alkaline solutions due to competition with OH^- ions. The arsenate adsorption decreases in acidic conditions due to protonation of arsenate ions.

(ii) $NaHCO_3$ provides the optimum pH condition for precipitation of Fe(II) if soluble Fe(II) ion is present along with arsenic in the water. At lower pH, precipitation of iron is slow whereas at higher pH, there remain some soluble iron in the water.

(iii) $KMnO_4$ oxidises difficult-to-remove arsenite ions to easy-to-remove arsenate ions. $KMnO_4$, a popular oxidizing agent used in water treatment, has another edge over its competitors as it exists as stable solid with high water solubility. $KMnO_4$ also oxidizes dissolved ferrous ion to insoluble ferric ion if ferrous ion is present in the water along with arsenic.

(iv) In acidic medium Mn (VII) of $KMnO_4$ is itself reduced to soluble Mn (II) state which is unwanted in drinking water. In the mild alkaline condition provided by $NaHCO_3$, Mn (VII) itself is reduced to Mn (IV) state and separates out as insoluble MnO_2 without leaving any residual dissolved manganous ions in the treated water.

(v) The arsenite oxidation efficiency for the Mn (VII)-As (III) system is higher under basic condition provided by baking soda than that under acidic conditions. The carbonate ions of $NaHCO_3$ accelerate oxidation of arsenite to arsenate.

(vi) The $FeCl_3$ is a Lewis acid. The positively charged Fe^{3+} ions attract negatively charged ions including arsenate and other particulates, grow and settle down quickly. $FeCl_3$ is more efficient than alum as a coagulant and does not leave any residual toxic substance in the water unlike alum which leaves aluminum ions which is suspected to cause Alzheimer disease. $FeCl_3$ coagulates sufficiently in the mild pH range provided by $NaHCO_3$.

(vii) The pH of about 8.3 initially provided by $NaHCO_3$ is brought to 7.3 by $FeCl_3$, producing H^+ ions by hydrolysis. The pH 7.3 is in the middle of the acceptable pH range of drinking water, which is 6.5 to 8.5. Though $FeCl_3$ is acidic and corrosive in aqueous solution it is safe in the presence of $NaHCO_3$ in the chosen dose.

(viii) The mild disinfectant $KMnO_4$ also kills the bacteria present in the water. Therefore, one does not need further disinfection of the water treated by Arsiron Nilogon provided cleanliness of the filter is maintained.

(ix) Iron (ferrous), if present in large concentration in the water along with arsenic, is oxidised into ferric state which coagulates like ferric chloride and hence is utilised as coagulant reducing the amount of ferric chloride dose.

(x) MnO_2 formed during Arsiron Nilogon also removes arsenic by adsorption.

In fact, the chemicals in the specified doses adjusts the pH of water favorably for adsorption of arsenic in minerals, supplies enough oxygen to oxidize iron to solid ferric form, supplies oxygen and manganese dioxide to oxidize and catalyze the oxidation of arsenite to removable arsenate form, and produces insoluble ferric coagulates and manganese dioxide to adsorb arsenate ions.

In summary we can say that in Arsiron Nilogon we just create a condition in the arsenic - contaminated water similar to the condition existing in an aquifer which does not have arsenic in the water.

The oxidation reactions taking place during Arsiron Nilogon:

Oxidation of dissolved ferrous iron by potassium permanganate in alkaline condition:

$$3Fe^{2+} + KMnO_4 + 5OH^- \rightarrow 3FeOOH + MnO_2 + K^+ + H_2O \quad (1)$$

Aerial oxidation of dissolved ferrous iron:

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O \quad (2)$$

Oxidation of arsenic (III) or arsenite to arsenic(V) or arsenate by potassium permanganate in alkaline condition:

$$3H_3AsO_3 + 2KMnO_4 + 4OH^- \rightarrow 3HAsO_4^{2-} + 2MnO_2 + 5H_2O + 2K^+ \quad (3)$$

Mechanism of arsenic removal in Arsiron Nilogon:

At the mild alkaline pH conditioned by sodium bicarbonate (baking soda), ferric chloride or Fe^{3+} ions coagulate and settle down. The coagulation of iron, being positively charged as ferric chloride is a Lewis acid, adsorbs negatively charged arsenate ions during the growth of the coagulations and while settling down. Thus, arsenic also settles down along with ferric coagulates and are separated from the water.

The role of potassium permanganate is to oxidise arsenic from difficult-to-remove arsenite form to easily removable arsenate form and to oxidise soluble coexisting ferrous iron to insoluble ferric state.

Sodium bicarbonate maintains the pH of water in mild alkaline condition where potassium permanganate itself remains in insoluble manganese dioxide (MnO_2) form while oxidising ferrous ion and arsenite. In acidic solutions, potassium permanganate itself would have converted to soluble manganous (Mn^{2+}) ions, while oxidising ferrous ion and arsenite and remained in the treated water, which is unwanted. Manganese dioxide being insoluble settles down along with iron coagulations and thus does not remain in the treated water.

Manganese dioxide formed from potassium permanganate also adsorbs some arsenate ions and helps in arsenic removal.

Cost of Arsiron Nilogon:

Recurring cost:

The recurring cost of the chemicals used in Arsiron Nilogon is approximately Paisa 0.5 per litre of water, ₹ 0.5 per 100 litre or ₹ 500 per 1,00,000 litres.

The cost estimation:

The cost of bulk Ferric Chloride anhydride at factory in Gujarat = ₹ 39 per kg + 18% GST and the cost of bulk Ferric Chloride 40% solution at factory in Gujarat = ₹ 16 per kg + 18% GST. The cost of bulk potassium permanganate in Gujarat is = ₹ 292 per kg + 18% GST. (The prices may be verified from Lakshita Chemicals, Sea Queen Avenue, Plot No. 62, Sec. 14, Kopar Khairane, Navi Mumbai, Dist Thane – 400709 (Mr. Rajesh Tyagi), Ph. 98211.47635/8652259666, Email: rtyagi09@yahoo.co.in). We have to add about ₹ 24 per 50 kg of each for transportation to Assam. The cost of bulk cooking soda in Assam is = ₹ 30 per kg.

The recurring cost can be further reduced for larger units by utilizing dissolved iron present in groundwater for coagulation and thus reducing the ferric chloride dose. The cost of potassium permanganate also can be reduced by proper aeration of the water before treatment by Arsiron Nilogon. Thus, for large units, the overall recurring cost can be reduced to about Paise 0.5 per litre or ₹ 500 per 1,00,000 (one lakh) litre.

Table 3.a.vi. Cost estimation for 1 lakh litre water in a Piped Water Supply Scheme:

Chemical	Quantity required	Approximate cost (₹)	Remarks
Cooking soda	<10 kg	< 300	The required quantity can be optimised and is <0.1g per litre
Potassium permanganate	≈ 400g	≈ 150	The quantity of potassium permanganate can be reduced by adequate aeration of the water
Ferric chloride	≈ 1.5 kg	≈ 50	We need less ferric chloride in presence of coexisting iron
Total cost per lakh litre of water		<500	

< - less than, ≈ - approximately

Table 3.a.vii. For 100 litres in household and small community units:

Chemical	Quantity required	Approximate cost (₹)	Remarks
Cooking soda	10 g	= 0.34	The required quantity can be optimised and is <0.1g per litre
Potassium permanganate	≈ 50 mg	≈ 0.02	The dose of potassium permanganate can be reduced by adequate aeration of the water
Ferric chloride	2.5 g	≈ 0.15	We need less ferric chloride in presence of coexisting iron
Total cost per 100 litre of water		≈ 0.51	

If we take into account the packaging, transportation, distributor and retailer charges, the total cost of the chemicals, especially, of potassium permanganate and ferric chloride increases for household and small community units. Thus, the recurring cost of the chemicals is remaining approximately Paisa 0.50 per litre or ₹ 1 per 200 litres, the quantity needed by a small family for 3-7 days.

Capital Cost of Arsiron Nilogon Units:

The capital cost of the technique depends on the capacity of the system. The Arsiron Nilogon method does not depend on the quantity of water to be treated or on the size of the treatment tank. For large treatment tank, a mechanical stirrer may be used. The units can be custom-designed and so the cost may vary according to design. The minimum costs estimated for some simple units of various sizes are as follows:

20 litre Household unit:

2 plastic buckets of 20 litre size for treatment and filter	= ₹ 300
2 small plastic taps	= ₹ 80
Sand and gravel	= ₹ 20
Total	= ₹ 400

40 litre Household / School unit:

1 plastic buckets of 40 litre size for treatment	= ₹ 300
1 plastic buckets of 20 litre size for filter	= ₹ 150
2 small plastic taps	= ₹ 80
Sand and gravel	= ₹ 20
Total	= ₹ 550

200 litre Household or Small Community / School unit:

1 plastic drum of 200 litre size for treatment	= ₹ 1000
1 plastic buckets of 40 litre size for filter	= ₹ 300
2 plastic taps	= ₹ 100
Sand and gravel	= ₹ 40
Total	= ₹ 1440

500 litre Household or Small Community unit:

1 plastic drum of 500 litre size for treatment	= ₹ 2500
1 plastic buckets of 200 litre size for filter and storage	= ₹ 1000
2 plastic taps	= ₹ 100
Sand and gravel	= ₹ 100
Total	= ₹ 3700

Large Community Piped Water Supply Scheme unit:

Additional dosing unit only is required between lifting cum aeration of water by pump and the sedimentation tank. The dosing may be done in a sequence to water flowing through a channel (made of plastic pipe or RCC) after aeration stage. The dosing may be controlled by adjusting a tap without needing a peristaltic pump. The estimated cost of the dosing unit:

3 plastic drums of 500 litre size for treatment	= ₹ 7500
20 ft long 10-inch-wide plastic pipe / channel	= ₹ 5000
Platform / stand / plastic taps / Miscellaneous	= ₹ 12500
Total	= ₹ 25000
Three peristaltic pumps (optional)	= ₹ 300000

Authentication of Arsiron Nilogon

- ***Third party technical evaluation*** by North Eastern Regional Institute of Land and Water Management (NERIWALM), Tezpur
- ***Research papers published in international journals of high repute*** (including Journal of Hazardous Materials in 2013 and several others later.
- ***Grant of patent:*** Arsenic removal from groundwater by oxidation-coagulation at controlled pH for domestic and community applications, ***Indian Patent No. 280737***, Application No. 704/KOL/2010, date of grant: 27/02/2017.

Third-party Technical evaluation of Arsiron Nilogon:

A third-party technical evaluation of Arsiron Nilogon was done at North East Regional Institute of Land and Water Management (NERIWALM), Tezpur, Assam a National laboratory under the Department of Science and Technology of Govt. of India. The report certifies Arsiron Nilogon as an efficient and safe method of arsenic removal from drinking water.

Table 3.a.viii: Some relevant water quality parameters reported by the third party after technical evaluation

Parameter	Tap water spiked with Arsenic		Tap water spiked with Arsenic		WHO guideline value
	Before treatment	After treatment	Before treatment	After treatment	
Arsenic (ppb)	431.0	1.1	262.0	0.9	10 ppb
Iron (ppm)	1.6	0.1	1.4	0.1	0.3 ppm
Manganese (ppm)	0.2	0.1	0.2	0.1	0.1 ppm
Sodium (ppm)	18.3	16.6	17.2	17.0	Not stated
Potassium (ppm)	3.2	1.9	2.6	2.0	Not stated
Alkalinity (as ppm $CaCO_3$)	103	86	88	84	200 ppm
Hardness (as ppm $CaCO_3$)	16.6	16.2	17.8	14.4	200 ppm

In addition to the third-party technical evaluation at NERIWALM, samples of arsenic-containing water before and after treatment by Arsiron Nilogon were also verified by testing physicochemical and biochemical water quality parameters at Indian Institute of Toxicological Research, Lucknow.

(b) Fluoride Nilogon Method:

Fluoride Nilogon is a method for removal of excess fluoride from contaminated groundwater for drinking purpose through phosphoric acid - crushed limestone treatment based on precipitation-adsorption developed by Dr. Robin Kumar Dutta, Professor of Chemistry, and his research group in the Department of Chemical Sciences of Tezpur University. The name 'Fluoride Nilogon' was coined in analogy to the name of 'Arsiron Nilogon', another technology developed by the same group for removal of arsenic and iron together from contaminated groundwater. The word 'Arsiron' was derived from **Arsenic** and **Iron (Ars + iron = Arsiron)**. Here, 'Nilogon' is an Assamese equivalent of 'removal' in English and 'अलग करना' in Hindi.

Limestone is usually easily available in all fluoride-affected areas of the world and of low-cost. Crushed limestone, when used in combination with phosphoric acid, removes fluoride most efficiently.

Phosphoric acid is an edible acid which is used as food preservative, in soft drinks like Cola and in water purification. It is a weak acid and only slightly stronger than crude lime juice.

Fluoride Nilogon is a two-stage batch process:

(i) Treatment with crushed limestone in presence of phosphoric acid and
(ii) Filtration, by any filter preferably sand-gravel

In Fluoride Nilogon, the fluoride containing water, mixed with a small quantity of phosphoric acid, is put into a crushed limestone bed plug-flow reactor and kept for a residence time of at least three hours. Fluoride is removed in the reactor. The water is filtered using a sand-gravel filter after three hours.

The Fluoride Nilogon filter

The unit consists of two-stages and can be custom designed for any capacity of treated water using two plastic or RCC container. The first stage is the crushed limestone bed plug-flow reactor. The reactor can be made of preferably a plastic bucket or plastic drum, fitted with a plastic tap towards the bottom. The second stage is a sand-gravel filtration made of a bucket or any other container with a plastic tap towards the bottom.

Limestone particle size: The size of limestone particles can be in the range of 0.1 to 1.5 cm. It is not necessary to have a particular size of limestone. Particles of size smaller than 0.1 cm may lead to clogging of water. Larger particle size will reduce the limestone surface area and hence reduce the effectiveness of the limestone.

While putting the limestone particles in the reactor, the larger particles may be put in first in the lower side and the smaller particles may be put in the upper side. The very small size particles may be rejected by sieving.

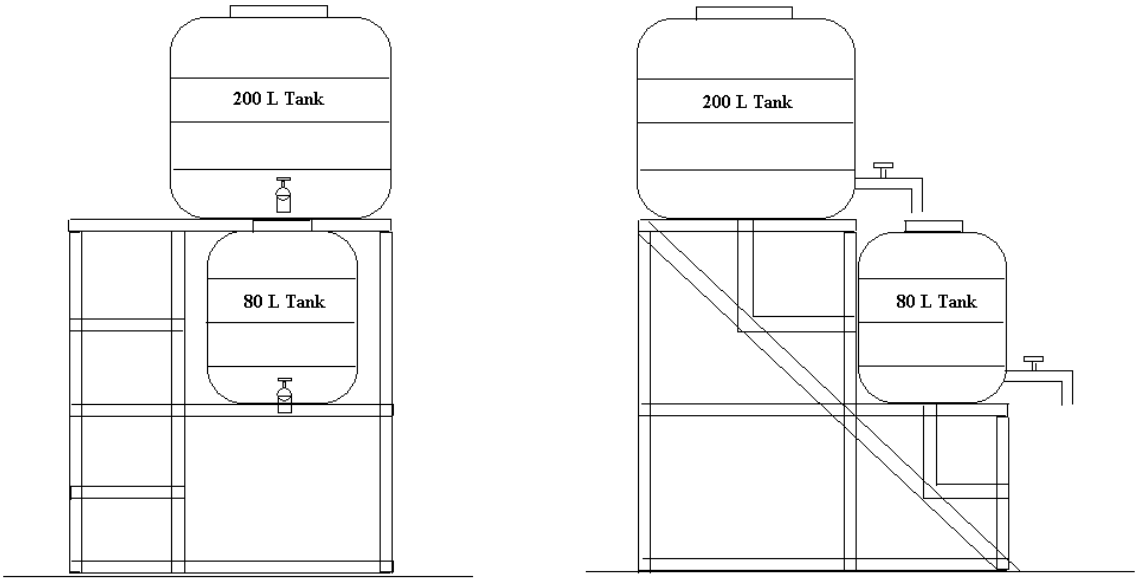
Household filter: A popular household unit consists of a plastic bucket of 40 litre capacity for the reactor and another 20 litre bucket for the sand-gravel filter (Figure 1). Both buckets are fitted with a plastic tap each towards the bottom. The 40 litre treatment bucket is kept at a level above the filter. The 40 bucket is filled with crushed limestone of 0.1 to 1.5 cm size. This limestone-filled bucket can hold about 15 litre of water. A larger size reduces the activity of limestone and a smaller size may lead to clogging. The filter should have a 6-7 cm thick layer of small 2-3 cm size gravel layer at the bottom. The rest of the bucket (at least 22 cm)

should be filled with clean medium size sand. There should be a thin porous cloth between the sand and the gravel layers to stop sand from going to the gravel layer.

Small community filter: For small communities like schools a 200 or 500 litre plastic drum can be used as the reactor and another 200 L drum can be used as the sand-gravel filter. After filling with crushed limestone, a 200 L drum can hold about 88 litre and a 500 litre drum can hold about 220 litre of water. The filter should have a 15-20 cm layer of small 2-3 cm size gravels, at the bottom, covered by a thin porous cloth, above which, there should be a 50-60 cm thick layer of clean medium size sand.

The inlet is from a tube-well through a pump. The water goes to a small plastic pot kept on the top of the limestone bed. The dose of phosphoric acid is added from the top to that pot while water is fed into the reactor. No regulated flow of the dose is required as the acid mixes with water very quickly.

The staging of the containers should be as low as possible to reduce inconvenience in dosing.



Front View Lateral View

Fig. 3.b.1. A Schematic Diagram of a Small Community (School) Unit:

Requirement of Materials, Equipment, etc.:

Household filter

40 Ltrs Bucket with Bucket Cover	: 1 No.
20 Ltrs Bucket with Bucket Cover	: 1 No.
¾" Plastic Water Tap	: 2 Nos.
Lime Stones	: 55 kg
Sand	: 1 cubic foot
1" size pebbles	: 4 kg
Synthetic net cloth	: 1 sq. foot
Acid Measuring Coop	: 1 No. (7 ml capacity)

8.5% Phosphoric Acid with Container : 2 L (For 7 months approximately with 15 L Water output per day per batch in 3 hours)

Small community filter

200 Ltrs Plastic Tank with Cover	: 1 No.
100 Ltrs Plastic Tank with Cover	: 1 No.
1" Plastic Water Tap	: 1 Nos.
1" Valve with bend and pipe	: 1 Nos.
Lime Stones	: 275 kg
Sand	: 10* cubic foot
1" size pebbles	: 20* kg
Synthetic net cloth	: 4 Sq. Ft.
Acid Measuring Coop	: 1 No. (37 ml capacity)
8.5% Phosphoric Acid with Container	: 12 L (For 7 months approximately with 90 L water per day per batch in 3 hours)
M. S. Iron Structure (staging)	: 1 No.

Working Principle of Fluoride Nilogon filter

For this, I need to tell you first how fluoride damages our tooth and bone. A hard solid compound, called hydroxyapatite, is a major constituent of our tooth and bone. The presence of a small percentage of another solid compound, called fluorapatite, makes our tooth enamel, the outer layer of the tooth, healthier and shining. That is why we need to have a small amount of fluoride, about 0.7 ppm (parts per million) in drinking water. Hydroxyapatite has a very strong affinity towards fluoride and strongly adsorbs it to form fluorapatite. If the drinking water contains high concentration of fluoride, then excess fluorapatite is formed in tooth and bone which damage them.

Now, in Fluoride Nilogon reactor, phosphoric acid reacts with limestone (calcium carbonate) and dissolves it to produce calcium ions. Then phosphoric acid, calcium ions and water react to produce hydroxyapatite in the reactor. This hydroxyapatite immediately starts adsorbing fluoride from water to form fluorapatite and thus removes fluoride from the water. This removal by adsorption continues for three hours. In addition to removal of fluoride by hydroxyapatite formed in the reactor, some fluoride is removed by precipitation of fluorite (calcium fluoride) and direct precipitation of fluorapatite in the reactor, which takes place within few minutes of putting the fluoride containing water-phosphoric acid mixture into the crushed limestone reactor. Thus, the principle used in Fluoride Nilogon may be related to the

Assamese proverb, "কাঁইটেৰে কাঁইট উলিওৱা।" meaning "To use a needle to remove a needle".

The solid hydroxyapatite, fluorapatite and calcium fluoride remains mostly in the reactor. A small percentage of these solids coming out along with the effluent water is removed from the water in the sand-gravel filter.

Dose of phosphoric acid

The required dose of phosphoric acid is fixed such that the initial concentration of phosphoric acid in the water put into the reactor is 0.00068 molar. Thus, for a 15 liter household unit, the amount of 8.5% phosphoric acid to be added is 7 ml (milliliter). The rounded doses for Fluoride Nilogon units of three different sizes are given in the Table 1 below:

Table 3.b.i: Dose of 8.5% phosphoric acid in Fluoride Nilogon

Size of crushed limestone reactor	Quantity of water to be treated	Volume of 8.5% phosphoric acid*
40 litre	15 litre	7 ml
200 litre	88 litre	42 ml
500 litre	220 litre	103 ml

*A small variation in the quantity does not matter.

The required dose of phosphoric acid may be slightly higher for limestone of some sources probably due to presence of a small percentage of lime (CaO) in the limestone.

Since hydroxyapatite is a strong adsorbent of fluoride, the fluoride will be completely removed from the water if we do not control the formation of hydroxyapatite. But a small concentration of fluoride in drinking water, 0.7 ppm as is advised by the World Health Organization (WHO), for healthy tooth and bones. Therefore we need to retain this small quantity of fluoride in the water. If we add phosphoric acid in Fluoride Nilogon to make its initial concentration in the water as 0.00068 molar, then the final fluoride concentration in the filtered water remains between 0.55-0.75 ppm. That is why we add only a small quantity of phosphoric acid which is enough to make the initial concentration of phosphoric acid in the water equal to only 0.00068 molar.

Pre-activation of the limestone-bed: The higher first dose of phosphoric acid is required for pre-activation of the crushed limestone-bed in the reactor. The rounded first dose is decided in order to make the initial concentration of phosphoric acid of the influent water as 0.01 molar for the first use. The rounded first doses of phosphoric acid for Fluoride Nilogon of three different sized are given in Table below:

Table 3.b.ii. The first dose of 8.5% phosphoric acid required for pre-activation of the crushed limestone bed in Fluoride Nilogon

Size of crushed limestone reactor	Quantity of water to be treated	Concentration of phosphoric acid	Volume of 8.5% phosphoric acid
40 litre	15 litre	0.01	103 ml
200 litre	88 litre	0.01	606 ml
500 litre	220 litre	0.01	1.5 litre

However, if the limestone is hard with high density and low porosity, then the activation may require higher dose and may have to be repeated for 2-4 times. For example, in the case of limestone from Chhattisgarh, the activation has to be done four times with gradually decreasing final phosphoric acid concentration as 0.02, 0.01, 0.005 and 0.002 M.

The Mechanism of fluoride removal by Fluoride Nilogon:

The following reaction scheme may describe the major mechanism of fluoride removal in Fluoride Nilogon:

$$CaCO_3(s) + 2H_3PO_4 \rightarrow Ca^{2+} + 2H_2PO_4^- + CO_2 + H_2O \quad (1)$$

$$CaCO_3(s) + 2H_2PO_4^- \rightarrow Ca^{2+} + 2HPO_4^{2-} + CO_2 + H_2O \quad (2)$$

$$Ca^{2+} + F^- \rightarrow CaF_2(s)\downarrow \quad (3)$$

$$5Ca^{2+} + 3HPO_4^{2-} + 3OH^- + F^- \rightarrow Ca_5(PO_4)_3F(s)\downarrow + 3H_2O \quad (4)$$

$$5Ca^{2+} + 3HPO_4^{2-} + 4OH^- \rightarrow Ca_5(PO_4)_3OH(s)\downarrow + 3H_2O \quad (5)$$

$$Ca_5(PO_4)_3OH(s) + F^- \rightarrow Ca_5(PO_4)_3F(s) + OH^- \quad (6)$$

Although both $H_2PO_4^-$ ($pK_{a2} = 7.21$) and HPO_4^{2-} ($pK_{a3} = 12.35$) are present in the pH range of treated water, the former dominates below pH 7.21 and the reaction in Eq. (2) is significant only above pH 6.21. The reactions of dissolution of $CaCO_3$ by the triprotic PA (H_3PO_4, $pK_{a1} = 2.12$), Eq. (1), the precipitation of CaF_2, Eq. (3) and the precipitation of calcium phosphate fluoride (fluorapatite, FAP) and calcium phosphate hydroxide (hydroxyapatite, HAP), Eq. (4&5) are completed rapidly. Precipitation of FAP should be preferred over precipitation of HAP due to lower solubility product of FAP than that of HAP. However, a high abundance of hydroxide ion in the system is also expected to precipitate HAP. The sorption or exchange of the remaining fluoride by the calcium phosphates, Eq. (6) probably continues for a longer time and completed in about 3 h as indicated by the continued increase in the fluoride removal till about 3 h. The neutralization of H_2CO_3 ($pK_{a1} = 6.35$) is probably rather slow and continues beyond 24 h as indicated by slow increase in the pH. Finally, it can be stated that a dominant defluoridation through sorption of fluoride by HAP, formed in situ, in addition to the precipitation of CaF_2, and sorption of fluoride by limestone makes the Fluoride Nilogon method highly efficient.

Fluoride removal by Fluoride Nilogon does not depend on initial fluoride:

It is very interesting to note that Fluoride Nilogon removes fluoride to the same level of approximately 0.65 ppm from any initial concentration in the range of fluoride up to 1 ppm to 20 ppm. This is because, in Fluoride Nilogon, the fluoride concentration is reduced from any initial concentration to about 2 ppm within a few minutes by precipitation. There is a limitation of precipitation to below 2 ppm due to thermodynamic solubility product restrictions. The adsorption by hydroxyapatite, that continues to remove fluoride after the fluoride concentration comes down to about 2 ppm, is same irrespective of the initial fluoride concentration.

It may be mentioned here that there is one household Fluoride Nilogon unit at Tekelangjun which has been removing fluoride from initial 20 ppm (highest in Assam) to 0.65 ppm with the same dose of phosphoric acid for over 2200 times of repeated use of same limestone.

Potability of the filtered water

Fluoride Nilogon is highly selective to fluoride. It removes fluoride from any initial concentration to 0.5-0.7 ppm without leaving any toxic residual or heavy metal in the water and retaining the potability of the water. The pH of the water after Fluoride Nilogon is about

7.5 (the acceptable range of pH for drinking water is 6.5-8.5) and suitable for drinking. Fluoride Nilogon slightly increases the calcium concentration in the treated water which is only beneficial to fluoride affected people. In fact, a calcium supplement keeps fluoride, consumed by us, away from absorption by our body. Similarly, the concentration of phosphate is also increased very slightly after Fluoride Nilogon, which can also be beneficial to fluoride affected people. All other relevant water quality parameters were also consistent with WHO guidelines (Table 3). The method is not affected by coexisting ions. The observed excellent performance of the Fluoride Nilogon has been attributed to a strong and highly selective sorption of F^- by in-situ formed hydroxyapatite in addition to precipitation of fluorite and adsorption by limestone.

Table 3.b.iii. Concentrations of metal ions and anions in sample before and after treatment by the PACLT. $[PA]_0$ = 0.68 mM; $[F^-]_0$ = 4.8±0.2 mg/L; source of water: supplied by PHED.

Parameter in mg/L except for pH	WHO guideline Value	Before treatment	After treatment
pH	6.50-8.50[a]	7.40	7.80
Dissolved solid	600	175	240
Suspended solid	NS[b]	12	8
Total alkalinity as $CaCO_3$	200	150	154
Total hardness as $CaCO_3$	200	155	160
Calcium	50	10.8	12.1
Phosphate	NS	0.14	0.11
Sulfate	500	60	62
Chloride	250	20	7
Nitrate	50	0.45	0.27
Cadmium	0.003	<0.001	<0.001
Chromium	0.05	ND[c]	ND
Cobalt	NS	ND	ND
Copper	2.0	<1.00	<1.00
Lead	0.01	<0.001	<0.001
Magnesium	NS	2.81	3.40
Manganese	0.40	<0.001	<0.001
Zinc	3.0	2.5	0.07
Sodium	200	94.69	85.96
Potassium	NS	4.22	3.12
Iron	0.30	0.013	<0.001

[a]Acceptable range for drinking, [b]NS: Not specified, [c]ND: Not detectable

Safety of using of phosphoric acid:

Phosphoric acid is a week acid like crude (undiluted) lemon juice. Its use in water purification is permitted by the Environmental Protection Agency of the United States of America (USA). Phosphoric acid is used as food preservative in some packaged foods. Phosphoric acid is also used in some soft drinks like Pepsi and Cola in concentrations almost similar to the initial concentration in influent water in Fluoride Nilogon. Phosphoric acid is corrosive to metals, floor, RCC containers, etc. It may burn and irritate soft skin then touched in high concentration. Phosphoric acid must be kept away from eyes and children. It may be noted here that the phosphoric acid added to the water in Fluoride Nilogon is completely neutralized by calcium carbonate (limestone) in the crushed limestone reactor. Calcium carbonate acts as a mild solid base in this case.

Estimation of cost for removal

The recurring cost of the chemicals is less than ₹ 1 per 100 L of water (less than 1 paise per litre). So, a family can get defluoridated drinking water for a week's use with the cost of just a cup of tea or a pair Tamol-Pan (betel nut-betel leaf). The capital cost is the cost of the two containers (plastic bucket or drum), two plastic taps plus some sand and gravels, and vary depending on the volume of water to be treated at one time. Fluoride Nilogon, as such, does not need electricity. But one may need electricity to pump water into a large crushed limestone reactor.

Availability limestone and phosphoric acid

Limestone is easily available around the world. In India, it is commercially available in most of the states. We have tested over 100 samples of limestone from different sources from different states, viz., Rajasthan, Chhattisgarh, Telengans, Andhra, Karnataka and Meghalaya. Roughly about 50% of the limestones are found to be suitable for use in Fluoride Nilogon. In Assam, there is plenty of limestone in Karbi Anglong and Dima Hasao districts. The cost of limestone is like the cost of stone chips used for RCC house building. The people from Karbi Anglong can obtain limestone of very suitable quality for Fluoride Nilogon from Delai Parbat (Hill) with the help of the General Manager of Bokajan Cement Factory of Cement Corporation of India, Bokajan or with the help of the Department of Geology and Mines, Government of Assam, Guwahati. The Bokajan Cement Factory has been very kind to provide us trucks of limestone as gift since 2004 for the laboratory research work leading to Fluoride Nilogon, its pilot test in the laboratory, its field trial at Dengaon and Tekelangjun in Karbi Anglong and now for use in actual Fluoride Nilogon purpose at schools and villages in Dengaon and Tekelangjun.

Phosphoric acid is available at low cost from some suppliers of whole sale market as concentrated 85% in 35 litre containers. It is safer to dilute it ten times to 8.5% by mixing 85% phosphoric acid and distilled water in 1:9 ratio, before giving it to layman users.

<u>Suitability of limestone suitable for fluoride Nilogon</u>

Limestone obtained from any mine may not be suitable for Fluoride Nilogon. For example, while the limestone from Delai Parbat or Bokajan in Assam is highly suitable for Fluoride Nilogon, the limestone from Umranso mine of Dima Hasao, Assam is not suitable. We have tested the suitability of about 100 limestone samples from different sources from Assam, Meghalaya, Madhya Pradesh, Andhra Pradesh, Telengana, Chhattisgarh, Karnataka and

Rajasthan and found that only about 60 percent of the limestone samples are suitable for use in Fluoride
Nilogon. The fluoride affected people of Karbi Anglong and Hojai districts are lucky to have limestone highly suitable for Fluoride Nilogon in the neighborhood.

Life of the limestone bed: We till now cannot say anything about the life of a crushed limestone bed in a reactor of Fluoride Nilogon since none of the reactors under use so far has been exhausted yet. Even the 220 liter small community Fluoride Nilogon unit installed at Dengaon on 15 March 2013 removing fluoride from initial 5 ppm and the 15 litre household unit installed in December 2014 at Tekelangjun removing fluoride from initial 20 ppm are still functioning very consistently with results the same as that of the beginning. It is estimated from the field experience that a limestone beds should work for about a century if the filter is used once in a day.

User-friendliness of Fluoride Nilogon: Let us give practical examples. The users of the small community as well as of the household Fluoride Nilogon units in Dengaon and Tekelangjun have been using the units on their own since their installation in 2013-2014 without our intervention except the supply of 8.5% phosphoric acid from time to time.

The users in Chhattisgarh and Orisha are highly satisfied with Fluoride Nilogon and that is why expansion of the implementation of the filters are going on.

(c) Semi-automatic Household Arsiron Nilogon filter:

This semiautomatic compact household filter is a mechanically operated unit, where pressing of three buttons release the required quantities of the chemicals in solution form. The treated water is filtered using a membrane rapped on a ceramic cartridge candle. The filter consists of two plastic coated stainless-steel chambers with three mechanical dozers for the three chemicals used mounted at the top. A blended membrane-ceramic filter candle is fitted with the upper chamber of the filter. The filtered water collected in the lower chamber is free from arsenic. The chemicals, *viz*., 10% cooking soda solution, 5% potassium permanganate solution and 25% ferric chloride solution in water controlled by three individual mechanical switches. On pressing a switch, the required volume of the respective chemical drops into water to be treated.

(d) Automatic dosing device for Fluoride Nilogon

The plug-flow mode electronically controlled automated unit can hold 250 mL of 8.5 % o-phosphoric acid which can be used to treat approximately 536 L of fluoride contaminated water in one batch. A plastic container was used to store the edible acid. We have optimized the automated unit so that it dispenses 7 mL of o-phosphoric acid to treat 15L of contaminated water in one batch, since all of the household units are of 15L capacity. However, the amount of o-phosphoric acid dispensed can be changed with the help of a smartphone. The device is started when contaminated water is filled into the limestone reactor so that o-phosphoric acid can react with the limestone to remove fluoride. Once started, the device dispenses 7 mL of o-phosphoric acid and then stops. It needs to be restarted for treating the next batch of fluoride contaminated water.

4. Methodology adopted for Development of the product/process (State briefly in 300 words).

Popularization of Arsiron Nilogon and Fluoride Nilogon:

The Do-It–Yourself technologies for removal of arsenic and fluoride from drinking water, viz., was done in a decentralized approach. Emphasis was given in installation of the filters by one-self with assistance of a trained volunteer of by NGOs with a user participation.

For this, we have organized a number of Workshops and Training programs for awareness and training on Arsiron Nilogon and Fluoride Nilogon including some in online mode after onset of CCVID-19 pandemic. The workshops and Training Programs received very good responses from all stakeholders including the affected people, NGOs, academic institutes, individual people and government agencies resulting in installation of Arsiron Nilogon and Fluoride Nilogon filters by:

a. Affected people themselves
b. By NGOs like Water Aid, Art of Living and many others
c. By some schools and colleges
d. Individual volunteers
e. By Government Agencies like National Program for Prevention and Control of Fluorosis, Gram Panchayat, PHED, etc.

We also organized Workshops and Training Programs at various villages, cities and academic institutes including other states by ourselves and in collaboration with various organizations, often on their own initiatives. We have prepared, printed and distributed information booklets on Arsiron Nilogon and Fluoride Nilogon, and Posters and one-page handouts on the two methods including health effects of arsenic and fluoride contamination of drinking water.

We also trained users on how to prepare the chemicals/chemical kits from materials available in the market in addition to providing a kit for the first-time use.

Research & Testing:

Research works for testing of arsenic and fluoride in drinking water and suitability of limestone for using in Fluoride Nilogon, etc., were conducted with standard methodologies. The instruments provided by the DST, especially an Atomic Absorption Spectrophotometer and an Ion Meter have greatly helped us.

5. Scientific/Technological Formulation giving underlying Basis (Provide sufficient details)

The main objective of the project was popularization of Arsiron Nilogon and Fluoride Nilogon through decentralized implementation. We have been able to show some notable works in that aspect during the project period. We have also done some research works in addition to testing of water samples for installation of filters and to monitor performance of Arsiron Nilogon and Fluoride Nilogon filters in Assam and other states. The scientific/technological formulations coming out of the project are:

(i) Study of simultaneous removal of arsenic, iron, manganese and other heavy metals by Arsiron Nilogon method:

This study has revealed that Arsiron Nilogon removes heavy metals, viz., Pb, Cd, Cu, Cr, Ni, and Co very well in addition to arsenic, iron, and manganese, and regulating the pH of treated water without affecting the potability of the water.

The removal of some heavy metals from initial concentration of 2 mg/L by the method has been found to increase in the order Cd (79.0%) < Co (94.8%) < Ni (94.4%) << Cu (98.0%) < Cr (98.3%) < Pb (99.5%) with its normal doses of chemicals of Arsiron Nilogon. Adsorption of the heavy metal ions with the amorphous coagulates of iron oxides is the major mechanism for removal of Ni, Cr, Cu and Co. On the other hand, while Cd and Pb are themselves removed predominantly through precipitation, the presence of these ions also facilitates precipitation of crystalline compounds of iron and manganese. A relatively lower removal percentage of Cd by OCOP is due to the soft acidic character as Cd^{2+} ion forms weak bonding with the oxide coagulates. While OCOP can remove As, Fe and Mn within 2 h, the removal of the heavy metals take a longer time 3–4 h. The most interesting finding of the present study is that the low-cost and simple OCOP method is capable of efficiently removing heavy metals of Cd, Co, Ni, Cu, Cr and Pb along with removal of As, Fe and Mn in one goes.

(ii) ***Study of suitability of limestone from different sources for Fluoride Nilogon:***

The study reveals the behaviour of different limestone samples collected from seperate geographical locations of India in fluoride removal from groundwater by PACLT method. It turned out that the limestone samples with higher BET surface area, total pore volume, and lower density, average pore diameter have a higher capacity for fluoride removal. Also, higher amount of Al and Fe were found in these samples, which may have played a decisive role in their fluoride removal and the final pH of treated water. PHREEQC supports this observation by predicting a decrease in pH of the treated water and an increase in the precipitation of fluorite and in situ formed HAp, with increasing Al_2O_3 and Fe_2O_3 impurities of limestone. Moreover, the analysis has predicted that high amount of CaO in limestone will reduce defluoridation.

Experiments conducted under varying reaction parameters showed that as $[F]_o$ increases from 3 to 20 mg/L, for achieving remaining fluoride concentration ≤ 1.5 mg/L after treatment with fixed $[PA]_o$ of 0.68 mM, the minimum required BET surface area and total pore volume of limestone increases from 1.24 to 2.70 m^2/g and 0.0078 to 0.0096 cm^3/g, respectively, while the maximum density decreases from 2.74 to 2.66 g/cm^3. Also, higher amount of Al and Fe were found in these samples, which may have played a

decisive role in their fluoride removal and the final pH of treated water. PHREEQC supports this observation by predicting a decrease in pH of the treated water and an increase in the precipitation of fluorite and in situ formed HAp, with increasing Al_2O_3 and Fe_2O_3 impurities of limestone. Thus, the present study demonstrates that a limestone's density, porosity, surface area and its impurities are the prime factors that determines its suitability for use in the PACLT method. These results of the study will help in selecting a suitable limestone sample for using in PAELD.

(iii) ***Field experience of Fluoride Nilogon in various states:***

We were waiting for about six years for the limestone beds of Fluoride Nilogon filters installed in Karbi Anglong, Assam, for user trial to exhaust to do regeneration study but there was no sign of any deterioration of the performance of the limestone beds for six years. So finally, we decided to publish the field experience and thinking the results to be of great importance, we had chosen to publish in India in Current Science.

The field study proved Fluoride Nilogon, fluoride removal by phosphoric acid-crushed limestone treatment in a plug-flow mode, as a very good rural technology for fluoride removal. The method involves pre-mixing of the fluoride-contaminated water with a dose of 0.463 mL of 8.5% PA per litre of water to give a concentration of 0.68mM of PA in the water, subsequent treatment of the water in a fixed-bed crushed limestone reactor of chip size 1-20mm for 3h and then sand-gravel filtration. The crushed limestone bed needs to be pre-treated with 0.01M PA. The method removes excess fluoride very efficiently from as high as 20mg/L to a desired level of 0.7mg/L. The removal is independent of the initial [F^-] and a higher dose of PA can totally remove fluoride. The pH of the treated water remains within 7.4-7.9 which is in the middle of the acceptable range of 6.5-8.5 for drinking. All other relevant water quality parameters for the treated water remain within the guideline values of the WHO.

The field units were found to work consistently over 4625 batches or 5½ years without needing any intervention like regeneration, replenishment or replacement of the limestone. The estimated life of the crushed limestone bed of a household Fluoride Nilogon unit used twice a day with 20mg/L feed water is a hopping 39210 batches or over half a century! The recurring cost of the treatment, the cost of PA only, ₹ 0.00467 (USD 0.000063) per L of treated water which is much lower than any other fluoride removal methods. Requiring only two containers, two taps, some limestone and some sand and gravels, the capital cost of 15 L household and 220 L small community Fluoride Nilogon units are only ₹ 600 (USD 8.51) and ₹ 4500 (USD 61.12), respectively. Finally, it can be concluded from the field experience that, high efficiency, high capacity of limestone, extremely low-cost, safe, environment-friendliness, non-requirement of electricity, non-requirement of regeneration, replenishment or replacement of any part for years (possibly decades), simple enough to be operated by a layman and user satisfaction prove Fluoride Nilogon as a very good rural technology to address the great world-wide problem of excess fluoride in drinking water.

The limestone, in general, has to be activated before use by treating once with 0.01 M phosphoric acid for three hours. However, for limestone from Durg in Chhattisgarh, the activation has to be done 3-4 time as the limestone is harder and has high density. A paper on the field experiences in Rajasthan, Chhattisgarh, Odisha and Karnataka is under preuaration.

(iv) Continuous fixed-bed column assessment for defluoridation of water using HAp-coated, limestone,

This study involved fluoride removal using HAP-coated-limestone in a continuous fixed-bed column. It was observed that the defluoridation capacity of HAP-coated-limestone increases with increase in bed mass and is maximum at a particular adsorbent size of 0.1-0.2 cm. However, it decreases with increase in flow rate and influent fluoride concentration. From the statistically calculated parameters, the Thomas model was found to be more reasonably accurate to predict the experimental fluoride sorption capacity of the column bed. The results obtained from column regeneration studies indicated that regeneration of the adsorbent is feasible with up to 30.29% removal efficiency in the 3rd cycle. This study indicated that the HAP-coated-limestone could fill in as a potential low-cost sorbent for the removal of fluoride ion from water in a continuous column mode, however, the method does not seem to be as competent as Fluoride Nilogon due to low capacity of defluoridation and limitation in regeneration.

(v) Fluoride removal from water by limestone-sludge:

The potential application of lime-sludge waste (LSW) from paper mills in removal of excess fluoride from water has been studied. The study has shown that LSW from paper mill can efficiently remove fluoride in presence of phosphoric acid through precipitation and adsorption. Geochemical model PHREEQ has predicted the model pH and precipitation products in coherence with experimental observations. The PHREEQ predicted remaining fluoride in treated water has been found to be better than experimental results. Fluoride removal was achieved from initial 10 mg/L to less than 1 mg/L in 30 min. The final [F^-] was found to decrease from 1.5 mg/L to 0.4 mg/L with decrease in initial [F^-] from 20 mg/L to 3 mg/L. The final [F^-] was also found to decrease with increase in adsorbent dose in the range of 5 - 35 g/L and increase in initial [PA] of 0.01 - 0.10 M. The observed 0.943 mg g^{-1} adsorption capacity of LSW is competitive among raw lime-materials and there are scopes for improving the adsorption capacity through modification of LSW and scaling-up of the process. The adsorption data fitted well with Freundlich isotherm and pseudo-second-order kinetics. The adsorption process is spontaneous and endothermic in nature. Regarding safety and environmental consideration, while the relevant water quality parameters of the treated water conform to the WHO guideline, the exhausted used LSW very well passes the TCLP test of the US-EPA. Thus, the present study indicates that the waste material of LSW, when used in combination with dilute PA, has a great potential to make an efficient, environment-friendly and low-cost defluoridating agent for getting potable water as well as for treating industrial wastewater.

(vi) Semi-automatic Household Arsiron Nilogon filter:

This semiautomatic compact household filter is a mechanically operated unit, where pressing of three buttons release the required quantities of the chemicals in solution form. The treated water is filtered using a membrane rapped on a ceramic cartridge candle.

The filter consists of two plastic coated stainless-steel chambers with three mechanical dozers for the three chemicals used mounted at the top. A blended membrane-ceramic filter candle is fitted with the upper chamber of the filter. The filtered water collected in the lower chamber is free from arsenic.

The chemicals, *viz*., 10% cooking soda solution, 5% potassium permanganate solution and 25% ferric chloride solution in water controlled by three individual mechanical switches. On pressing a switch, the required volume of the respective chemical drops into water to be treated.

(vii) Automated dosing device for Fluoride Nilogon

An automated unit of Fluoride Nilogon was designed and fabricated using electronic valves, control unit using Arduino and amplifying devices. The plug-flow mode automated unit can hold 250 mL of 8.5 % o-phosphoric acid which can be used to treat approximately 536 L of fluoride contaminated water. A plastic container was used to store the edible acid.

The automated unit is optimized so that it dispenses 7 mL of phosphoric acid to treat 15L of contaminated water in one batch, since all of the household units are of 15L capacity. However, the amount of phosphoric acid dispensed can be changed with the help of a smartphone which is controlled the control unit i.e., Arduino. The device is started when contaminated water is filled into the limestone reactor so that phosphoric acid can react with the limestone to remove fluoride. Once started, the device dispenses 7 mL of phosphoric acid and then stops which will control by control valves. It needs to be restarted for treating the next batch of fluoride contaminated water. The performance of the automated unit was tested in the laboratory and its performance was found to be highly encouraging.

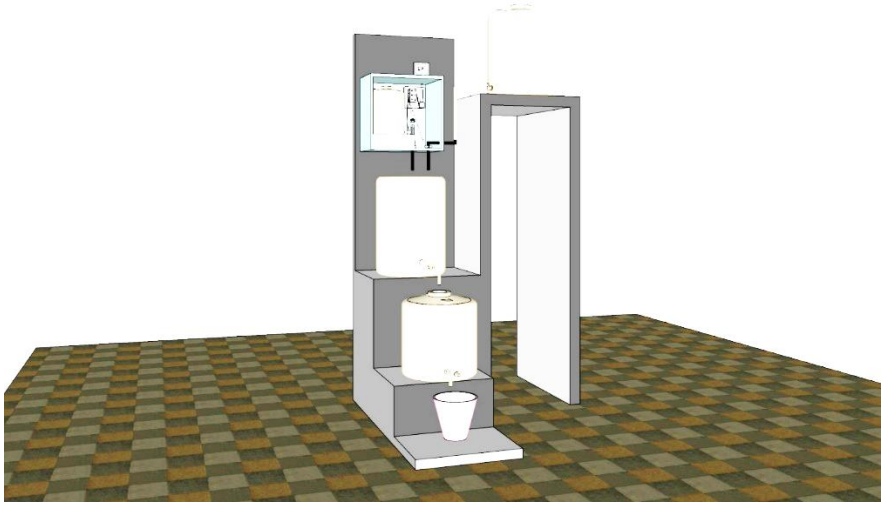


Fig.5.vii.a: Schematic diagram of the dosing unit for Fluoride Nilogon

Fig.5.vii.a shows the schematic diagram of the dosing unit for Fluoride Nilogon. An arduino is used to control the whole system using a suitable program. The control signal found from the arduino is not sufficient to drive the control valves. Therefore, voltage amplifiers are developed using operational amplifier (IC-741) and current amplifiers are developed using transistor to attain suitable voltage and current to drive the control valves. The schematic diagram of electronic control circuit is shown in Fig.5.vii.b.

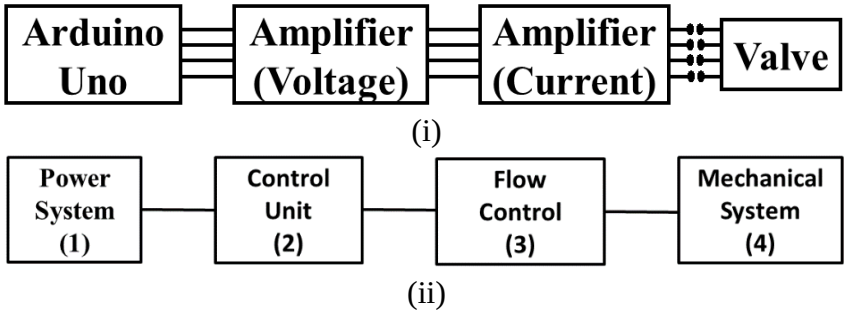


Fig.5.vii.b(i-ii): The schematic diagram of electronic control circuit

The mechanical parts consisted of 3 solenoid valves. For collecting 7 mL of Phosphoric Acid (PA) into the custom-made glass tube, the 1st solenoid valve (which is normally closed) was opened for 400 mS (milliseconds) while the other two valves were kept closed. The amount of liquid flow is calibrated with time i.e., time interval between opening and closing the valves. The Once 7 mL of PA is collected into the tube, the 1st solenoid valve is closed and the other two valves were opened to dispense this 7 mL of PA to the reservoir.

Different circuit diagrams for operating the system:

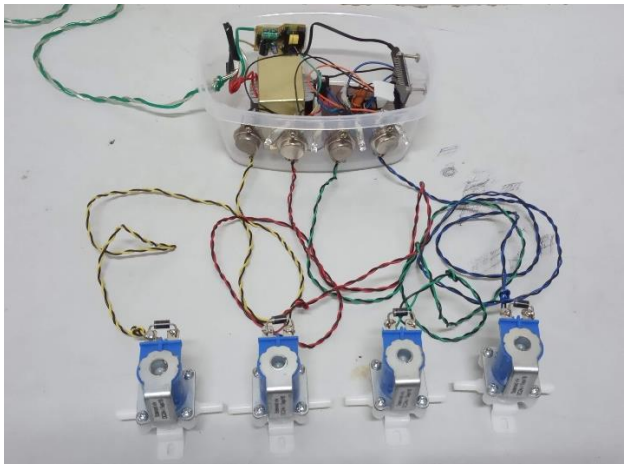


Fig.5.vii.c. Electronic components in the automated Fluoride Nilogon device

Functions of each Solenoid Valves:

1st Solenoid Valve: To allow flow of PA from the PA chamber into the glass tube (250 mL capacity)

2nd Solenoid Valve: To dispense PA from the glass tube

3rd Solenoid Valve: For maintaining air-pressure inside the tube

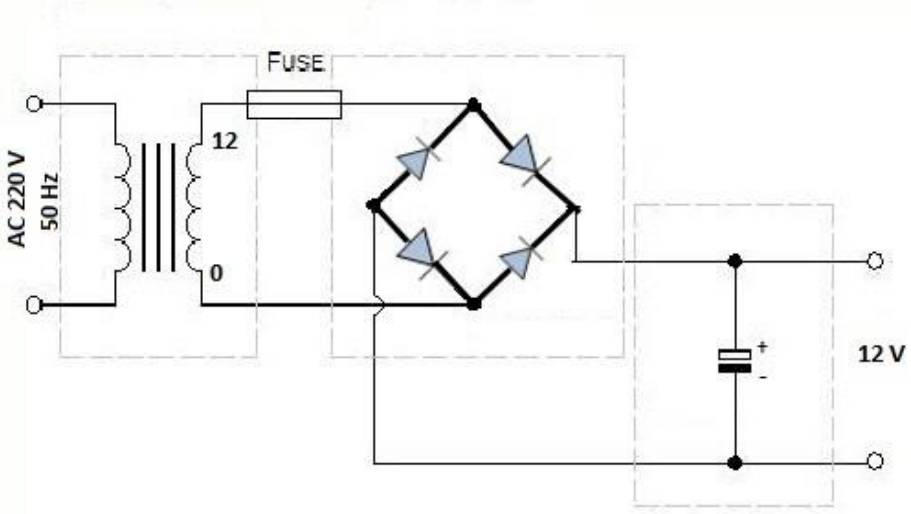


Fig.5.vii.d: Power supply unit

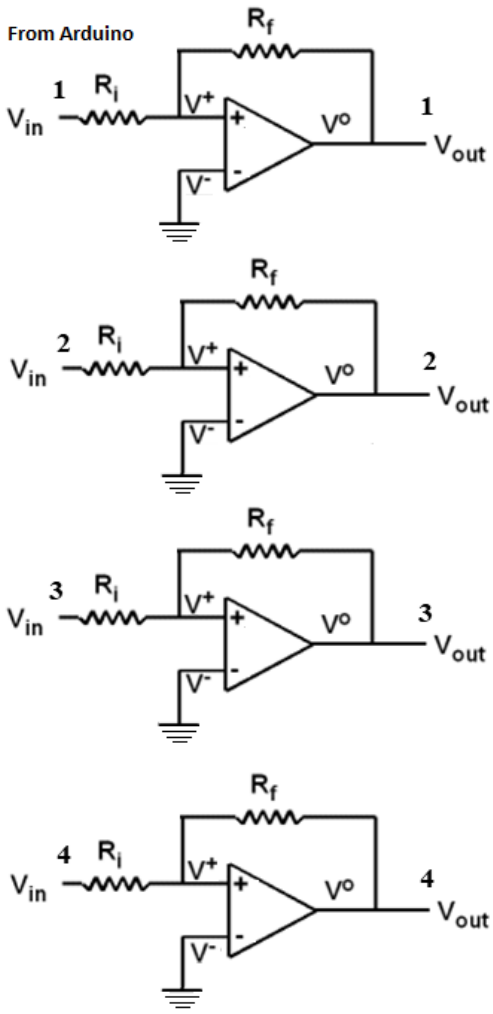


Fig.5.vii.e: Voltage amplifier unit

6. Further Work required, if any to get full Benefits or enhance Utilization.

(i) Continuation of the technical support from Tezpur University to the increasing number of arsenic and fluoride-affected people who want to install and use the filters and to increasing number of NGOs and Government agencies who want to implement the technologies in the affected areas is required

(ii) Further detail research on removal of heavy metals including mercury by the Fluoride Nilogon method is required as it will solve more than one issues in one go which is also very low-cost and safe.

(iii) Further research on reducing TDS (Na^+, SO_4^{2-}, Cl^-) and NO_3^- along with removal of fluoride is required as these problems are often associated with excess fluoride.

7. Recommendations for Utilization of the product/process. Give Concrete Steps.

(i) **Setting up of a Center for Safe Water at Tezpur University:** The technologies of Arsiron Nilogon and Fluoride Nilogon are being used by increasing number of people. New filters are being installed by villagers almost every day with the help of trained volunteers. Implementation of the technologies by NGOs and Government agencies is also expanding and new NGOs and Government agencies are also coming up. As a logical conclusion of this project which we believe, has been highly successful, **Center for Safe Water at Tezpur University** at Tezpur University may be set up for providing technical support to all water quality-affected people and agencies working for them, and also for carrying research works and offering related training courses.

(ii) Considering the performance and popularity of Arsiron Nilogon and Fluoride Nilogon methods, The DST and the Government may take some initiatives for promoting them through different agencies in the affected areas in the country.

Signature of the PI: 

Date: **26 April 2021**

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