AN OVERVIEW OF REMOVAL OF FLUORIDE IN FROM POTABLE WATER IN CHHATTISGARH

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ABSTRACT

Fluoride is an inorganic element prevalent in nature, a certain amount of which is useful for our body, it enter in our body through water, food, and other products such as toothpaste. A certain amount of fluoride in water is beneficial for our body, but excess amount of fluoride in water is harmful for our health. Such as skeletal fluorosis, curvature of bone in different places of our body, dental fluorosis, thyroid, brain, and endocrine glands etc. There are many methods are available for removal of excess of fluoride, some of which are known here, such as ion exchange method, sol-gel method, adsorption method and electro-dialysis method. The description is available. Presently here a comprehensive overview of fluoride removal techniques, advantages and limitations. On the use of several methods in the laboratory and concludes that remediation procedures should be tailored to local needs and site-specific to the conditions prevailing because Every technology has its certain limits.

Keywords— Sol-gel method, fluoride, thyroid , fluorosis and electro-dialysis

INTRODUCTION

On the increasing of population and industrialization, the demand for water is increasing, to meet the requirements of which fresh water is being used in large quantities. Only 3% of the available water on earth 1.38 x 10^9 km is available as fresh water. Out of which 1.74% in glaciers. And the remaining 1.7% is available in the form of groundwater. And very little i.e. 0.0132% of the total water available on the earth is available in rivers, ponds and lakes, most of which is used in the disposal of waste materials and by humans. polluted due to the activities carried out. India comes in the count of 23 countries in the world where fluoride-contaminated water is causing health problems. Fluorosis was detected in four states of India in 1930, which increased to 13 states in 1986, then two more states were added in 1992. Till now, 19 states and 177 districts of India

have been detected with fluorosis. Severely fluorosis-affected states are Haryana, Rajasthan, Uttar Pradesh, Andhra Pradesh, Gujarat, Punjab, and Tamil Nadu. The maximum concentration is observed in the Rewari district of Haryana.

Bhatnagar et. al(2011) Fluoride pollution is a matter of great concern in the world. The WHO has designated fluoride as the second most important water contaminant after arsenic and nitrate which causes major health problems. Fluoride enters the groundwater through the breakdown of fluoridated rocks or by human activities. Fluoride enters the groundwater through different minerals in which fluoride is found, such as basalt, granite, cyanide, biotites, and topaz. Fluoride then enters the human body through water intake by humans. In addition to natural sources, industries also have a role in fluoride pollution. Industries treat water containing high concentrations of fluoride, such as ceramics production, semiconductor manufacturing, glass, and beryllium extraction. plants, coal-fired power stations, etc. The amount of fluoride in water from these industries is more. The amount of which is 10 to 1000 ml liter, 200 million people around the world are dependent on fluoride-contaminated water, which is more than the standard limit of 1.5 prescribed by WHO, which can be harmful and beneficial for human health.

Meretzky p. et, al.(2011) Fluoride is an essential element for the health of teeth and skeleton. WHO has set the standard limit of 0.5 to 1.0. Drinking water with fluoride above 1.5 is harmful to human health, causing dental or skeletal fluorosis. Fluorosis has become an endemic problem in the world, especially in the mid-latitudes. Various engineering processes such as coal, power plants, rubber, fertilizer production, semiconductor manufacturing, etc., have resulted in increasing fluoridated wastewater. Various methods have been developed for the removal of excess fluoride in drinking water, including the use of coagulation ion exchange columns, the use of membranes, and electrolysis. Chemical methods: The cost of using these methods is high, which is not suitable for the practice of developing countries.

Chen.et,al(2010) necessary to treat water with disinfection. The reason for the pollution of groundwater is the ever-increasing population, increasing industrialization and urbanization, and uncontrolled use of water in the period of economic development. Continuous spraying of pesticides, fungicides in the fields, disposal of harmful wastes, disposal of waste and water coming out of industries and factories, sewage disposal, etc. Water in many parts of India is not

only useful for human use but also not useful for industries in this research. The main purpose of monitoring the issues is to maintain groundwater's usefulness in the future so that groundwater is safe for the future. Fluoride is an inorganic pollutant found in India's groundwater, whose removal and its side effects are described.

SOL-GEL METHOD

"Formation of an oxide network through polycondensation reactions of a molecular precursor in a liquid". A sol is a stable dispersion of colloidal particles or polymers in a solvent. The particles may be amorphous or crystalline. An aerosol is particles in a gas phase, while a sol is particles in a liquid, A gel consists of a three dimensional continuous network, which encloses a liquid phase, In a colloidal gel, the network is built from agglomeration of colloidal particles. In a polymer gel the particles have a polymeric sub-structure made by aggregates of sub-colloidal particles. A gel may also be formed from linking polymer chains. In most gel systems used for materials synthesis, the interactions are of a covalent nature and the gel process is irreversible. The gelation process may be reversible if other interactions are involved.

-The idea behind sol-gel synthesis is to "dissolve" the compound in a liquid in order to bring it back as a solid in a controlled manner.

-Multi component compounds may be prepared with a controlled stoichiometry by mixing sols of different compounds.

-The sol-gel method prevents the problems with co-precipitation, which may be inhomogeneous, be a gelation reaction.

-Enables mixing at an atomic level.

-Results in small particles, which are easily sinterable.

Sol-gel synthesis may be used to prepare materials with a variety of shapes, such as porous structures, thin fibers, dense powders and thin films.

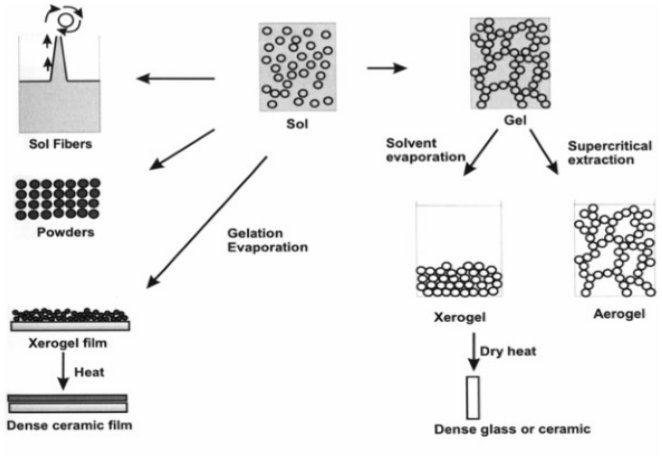

Fig1. Flow sheet digamma of Sol-Gel method

If the gel is dried by evaporation, then the capillary forces will result in shrinkage, the gel network will collapse, and a xerogel is formed. If drying is performed under supercritical conditions, the network structure may be retained and a gel with large pores may be formed. This is called an aerogel, and the density will be very low. A record is < 0.005 g/cm^3.

Physical properties of silica aerogels

Property	Value	Comments
Apparent Density	0.003-0.35 g/cm^3	Most common density is ~0.1g/cm^3
Internal Surface Area	600-1000 m^2/g	As determined by nitrogen adsorption/desorption
% Solids	0.13-15%	Typically 5% (95% free space)
Mean Pore Diameter	~20 nm	As determined by nitrogen adsorption/desorption (varies with density)
Primary Particle Diameter	2-5 nm	Determined by electron microscopy
Index of Refraction	1.0-1.05	Very low for a solid material
Thermal Tolerance	to 500 C	Shrinkage begins slowly at 500 C, increases with inc. temperature. Melting point is >1200 C
Coefficient of Thermal Expansion	2.0-4.0 x 10^{-6}	Determined using ultrasonic methods
Poisson's Ratio	0.2	Independent of density. Similar to dense silica.
Young's Modulus	10^6-10^7 N/m^2	Very small (<10^{4}x) compared to dense silica
Tensile Strength	16 kPa	For density = 0.1 g/cm^3.
Fracture Toughness	~0.8 kPa*m$^{1/2}$	For density = 0.1 g/cm^3. Determined by 3-point bending
Dielectric Constant	~1.1	For density = 0.1 g/cm^3. Very low for a solid material
Sound Velocity Through the Medium	100 m/sec	For density = 0.07 g/cm^3. One of the lowest velocities for a solid material

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ADSORPTION METHOD

Proponents of adsorption technology have argued that adsorption technology is economically superior and produces higher-quality water. The adsorption method for fluoride removal has been widely studied in depth in recent years to achieve high There is increasing interest in valence metals and functional sorbates . The adsorption of fluorides on solid adsorbents occurs via three steps (1) transport of fluoride ions to the outer surface of the adsorbent around the adsorbent particle External mass transfer from the bulk solution across the nearby boundary layer is called (2) Adsorption of fluoride ion on the surface of the particle (3) The adsorbed fluoride iron is probably structural within the adsorbed particle depending on the chemistry of the solids The elements exchange with each other or the adsorbed fluoride ions are redistributed to the internal surfaces. Porous materials depend on the ions of the fluid. Adsorption extends over the entire surface of a solid where the solid binds to the surface or is attached to it by weak intermediate forces. An important characteristic of adsorption studies that ensure the suitability of adsorbents for practical use is Adsorption capacity is selective for a fluoride ion, regenerating capability, compatibility, particle, and pore size, and cost but fluoride removal efficiency is always dependent on raw water quality and its profile. mean initial fluoride variability PH temperature, contact time, and adsorbent dosage . Among the parameters listed above, the selectivity of the adsorbent for fluoride ions appears to be the most important adsorbent characteristic as some adsorbents have been Tested have shown high completeness but at the same time water treatment plants fail under real conditions due to reduction in adsorption capacity due to effect on the binding of functional sites of adsorbent by secondary co-ions present in treated water. The fluorine concentration, defined as the ratio of the capacity of one component to the capacity of the other, reaches a steady level of selectivity as the concentration approaches zero. That is why the major work of experts and scientists has been to develop highly selective adsorbents with low-cost, efficient, and environment-friendly but high adsorption capacity . Various types of adsorbents and their available resources have been investigated, including activated carbon activated alumina bauxite contains hematite hematite . polymeric resins activated rice bran brick Powdered Psava Red clay, charcoal,ite, fly ash that Moringaoleifera Granulated ceramic chitin, chitosan and alginate modified ferric oxide hydroxides zirconium and cerium modified materials titanium derived absorbents schwertmannite modified cellulose clay and magnesium modified Sorbents Nanoformulated

different metal oxides and hydra oxides from the adsorbents listed above show very good results and very high adsorption capacity even when the amount of fluoride is low. But more than half of the adsorbents lose their capacity to remove fluoride. Most of the adsorbents have a minimum limit of 2 mg / liter to remove fluoride, so they are not suitable for drinking water. Some of them work only at very high pH. Like activated carbon which only PH < 3. 0 [15] but are effective at removing fluoride

ION EXCHANGE METHOD

Ion exchange technology is well known for the purification of wastewater, ion exchange can be accomplished with ion exchange or synthetic polymeric materials (Bhakuni) and Sass, 1964, Kuneen and McGarvey, 1948, Majumdar unpublished, Majumdar and Ray, 1986, Runaska L, al 1051). A very good method has been developed using ion exchange, although the ion exchangers process will be effective only when the concentration of fluoride is 10 Mg / 1 [Kumar unpublished] Significantly associated with the removal of fluoride from wastewater Published findings (Apparao and Karthikeyan 1086 APHA et, al] 1992 Arulanatham et al 1992 Behl 1975 Barbier and Majuni 1984 Bhakuni and Shastri 1963 Bulusu) 1984 Bulusu and Navlakhe [ed], 1992 Bulusu et al 1979 Kumar et al 1992 Michael Nitrite and Hammond,1938 Meenakshi El al 1991 Rabowski and Miller 1981 RubelaurWusli 1979 Savinelli and Black 1958 Schoemann and Botha 1985 Sitapatirao 1964 Srinivasa 195 and Thergaonkar and Navlakhe 1971 Although there is little work on the removal of fluoride from SPL leachates using ion exchangers The phase extraction chromatography technique is selective for the extraction of ions. A solid substance acts as the stationary phase in liquid-solid chromatography and the extraction is dependent on grain-based equilibria between the stationary and mobile liquid phases. In reverse-phase chromatography, liquid ion exchangers are used. Solid support is applied to silica gel (such as charcoal) Exchanger phase (liquid) is changed to solid by impregnation Recent selective studies on natural and artificial SPL leachates Removal of fluoride in natural SPL leachates High levels of fluoride up to 575 mg/liter

ELECTRO-DIALYSIS METHOD

Electro-dialysis technology removes ionic particles from aqueous solutions through ion exchange membranes by electromotive force. Used to remove ionic contaminants that pollute water. Electro-dialysis is similar to reverse osmosis. Electro-dialysis except with electricity. This

method is not useful for rural use due to power consumption. [Adhikari. et al]De-fluoridation treatment of brine containing fluoride up to 10 ppm with TDS up to 5000 ppm with an energy requirement of < 1KWN /Kg of salt Is done and it is given 600 ppm TDS and 1. De-fluoridation of 3000 ppm of total dissolved solids [TDS] and 3 ppm of fluoridated water to produce potable water by treating brine using an electro-dialysis process [Amir et al] [Annour. et, al.] compared electro-dialysis using CMX -ACS membranes to remove fluoride from artificial water and groundwater in the city of Youssoufla and water brought within WHO permissible limits [Saheli et al] of the Moroccan city used electro-dialysis and chitosan in addition to these two processes for the de-fluoridation of underground brackish water and also treated fluoride-free water with 3mg/l fluoride and 3000 mg/l total dissolved solids [Kabe et al]Applied voltage, experimented with the removal of fluoride from aqueous solution by electrolysis under various operating parameters including feed flow rate, fluoride concentration and the effect of sulfate and chloride ions, and found that the initial fluoride concentration in the feed solution increased with increasing amounts of the initial fluoride concentration. The deposition activity increases and the fluoride removal also increased with the increase in the applied capacity. On the other hand, changing to feed fluoride left performance unaffected. Chloride ions are unaffected by sulfate ions, yet have an effect on the performance of the dissociation of fluorides from water even when chloride and sulfate ions are available.[argun et al] The use of electro-dialysis with SB 6407 ion exchanger membranes to remove fluoride, which contained 20.6 mg/l fluoride, reduced fluoride from water intended for drinking purposes to 0.8 mg/l [lanthanide et ,al] made a cost-effective measure of fluoride removal by means of electrolysis with an operating cost of 0.154 m 3 capital coast trial of 833,207 with 5000 /liter capacity for 2200 m 3 /d water use according to Moroccan standards for rural areas Used for construction of the industrial plant

HEALTH IMPACT

Ullah.R.(2017) Fluoride has beneficial as well as harmful effects on the teeth, therefore it is necessary to control the amount of fluoride, whether it is natural or artificial. Which we use daily. Therefore excess amount of fluoride can have harmful effects on our bodies. Fluoride control research is aimed at increasing public awareness and treatment of the harmful effects of excess fluoride on the body. Most of the fluoride consumed by mouth is absorbed through the gastrointestinal tract. In addition, fluoride enters the body in small amounts through breathing

and dermal absorption. Its biggest sources are fluoridated water and dental products. Fluoride is absorbed in tissues that are mineralized. Fluoride absorption is beneficial for children as they grow. And. Fluoride in the body decreases with age. The amount of fluoride varies when the amount of fluoride in the plasma is low so that fluoride is able to cross the placenta. The placenta helps prevent excess fluoride intake. And protects the fetus from excess fluoride intake. Absorption is done. It passes through the serum to the mineralized tissue and collects and the rest is excreted in the urine. The excretion of fluoride accumulated in the urine is dependent on many factors such as plasma fluoride levels, glomerulus, filtration rate, pH of the urine, and stream. Chen.n.(2010) It is necessary to manage harmful elements like fluoride for health, fluoride is harmful to health as well as beneficial. But excessive intake of fluoride is responsible for dental caries, bone fluorosis, and lesions of the thyroid, brain, and internal secretory glands.

Cheng.j.et,al (2014) The WHO-prescribed limit for fluoride is 1.5mg/liter. Drinking water containing more fluoride than this can have harmful effects on the teeth. May cause skeletal fluorosis. Consumption of water containing 6 mg/L of fluoride and water containing 10 mg/L of fluoride can cause fluorosis in humans.

He.j.et,al (2020) Some recent studies have revealed that consumption of fluoride-containing water has an effect on teeth and skeletal fluorosis as well as soft tissues. This fluorosis has been named non-skeletal fluorosis. The fluoride is more of fluoride with affecting the Kamomal tissue. The volume nervous system also affects the liver endocrine kidney reproductive system and metaphorical and functional organs. In Tanzania, 14 to 17-year-olds are affected by Fluorosis handicapped, a serious type of fluorosis that is a serious type of fluorosis that causes a problem for the victim to roam around it occurs.

King.L.el,al.(2019) Creating a long -term fluoride -containing water to drink, causes damage to the normal metaphorical activities of the body, causing damage to scale fluorosis tooth fluorosis, and bone.

EFFECT ON REPRODUCTIVE SYSTEM

Ehinoy.N.et.al(1989) Schwarz and Milne Messer et.al told through their research that fluoride is an essential nutrient. Tao and Sattie did experiments to show the necessity of that and told that fluoride is related to reproduction. These people reported through their experiment that fluoride

does not have an essential function for reproduction in female rats. Major et al. stated that fluorine deficiency can lead to impaired fertility and fertility in female rats. Kor and Singh reported that intake of fluoride (500 ppm to 1000 ppm) for 2 to 3 months in rats resulted in the reduction of testicular maturation and variation in spermatids. Simultaneously, the spermatogenic endings and spermatogenic tubules were observed to be destroyed.

Long Het, al. (2009) Inmost parts of the world, man-made fluoridation of water supplies is being attempted in an attempt to reduce dental caries caused by fluoride. There is growing evidence that the problems caused by fluoride are causing toxic effects, clinical experiments show that fluoride has harmful effects on male fertility, with functional and structural defects in 2 to 5 spermatozoa. 6,8 There is a decrease in the number of spermatozoa. Four, seven 9, 11 disturb the levels of reproductive hormones and 9, 12 alter the epididymis, and 13, 14 accessory reproductive glands. All of the mechanisms explored in this review are believed to pervade the male reproductive process by altering the levels of various hormones, impairing the shape and functional behavior of spermatozoa, and inhibiting spermatogenesis.

Oriz.Perez et.al(2003) Human exposure to fluoride is a public issue. The risk to human life to fluoride is public. The main sources of fluoride exposure are through the consumption of contaminated groundwater and tap water. Fluoride concentration in drinking water greater than 1.5 mg/l has various biological effects such as skeletal fluorosis, dental fluorosis, reproductive effects, and neurological effects that have been reported in humans and experimental animals. Reproductive effects are not fully described in males. And conflicting data are available in the literature. Male rats treated with NaF (10 ml/kg/day for 30 - 50 days) have reported a decrease in sperm motility and serum testosterone levels. In addition, structural defects were observed in the flagellum of spermatozoa, nucleus and acrosome, and epidermal spermatozoa in rabbits treated with fluoride (10 mg/ NaF /Kg/day for 18 months). When exposure time was further extended to 29 months, rabbits' Spermatogenesis stopped.

SOME OTHER ADVERSE EFFECT

Meiyah et.al(2020) Moderate intake of fluoride is beneficial to human health. Exposure to high concentrations of fluoride, however, causes a variety of disorders in humans. Epidemiological tests have suggested that low to moderate intake of fluoride may cause fluorosis. A survey of

children in the US found confounding changes in kidney and liver function data associated with fluoride exposure.

Yin.S.et, al.(2015) It has been proved by experiments that exposure to excessive fluoride for a long time or consuming excessive fluoride water has adverse effects on the brain, bone, testis, liver, spleen, and kidneys of animals and humans. It has been reported in many studies that factory factories by humans Excessive use of fluoride in industries have adverse effects on animals, humans, and plants. Fluoride has harmful effects on bone, brain, kidney, and spinal cord. Lowers intelligence and reduces photosynthesis. The review shows that the majority of the harmful effects of fluoride compounds on animals have focused on the reduction of fertility. In vitro, studies have been the mainstay of the investigation of fluoride exposure in humans because it is important for many aspects of human biology. Aspects very well as genome sequencing projects agree on the biological functions of these organisms in both humans and mice. The functional organ of the reproductive system is the ovary. Which releases the mature egg for fertilization known in many studies. High concentrations of fluoride cause damage to the ovary. Many studies have precisely defined the changes in gene expression that occur.

SKELETAL EFFECT

Srivastava. S., et.(2020)The pathophysiological condition is skeletal fluorosis which is caused by high concentrations of fluoride. Fluoride enters our body either through intake or through breathing. Deposition of high concentrations of fluoride in bones leads to bone resorption. , Due to which the calcium level changes in the tissues of the bones. Due to this, the balance of bone mineral metabolism gets disturbed. On the basis of severity, skeletal fluorosis is divided into 3 orders, moderate and severe, and mild skeletal fluorosis, symptoms of skeletal fluorosis are osteosclerosis, sporadic pain, calcification of ligaments, and joint pain. There is stiffness in the joints. Apart from these symptoms, there are some other symptoms of skeletal fluorosis such as neurological deficits, muscle wasting, skeletal deformities, and diffuse stiffness in many joints of other organs arising from the bones of the spine. The movement of the ribs also slows down and the chest becomes shaped like a drum, due to which there is difficulty in breathing, in addition to this, due to the firmness of the joints, there is a defect in the ability to spread in the hips, knees and various joints. becomes bedridden, skeletal fluorosis is most susceptible to 30 to 50 years of age, the longer the exposure to fluoride, the greater the prevalence of skeletal fluorosis based on

epidemiological evidence Several factors affect the amount of fluoride deposited such as low calcium intake, poor nutritional status and increasing age which further contribute to fluorosis progression.

RENAL EFFECT

It is very difficult to calculate in the literature the toxic effects on the kidneys in humans. Exploratory and experimental studies on methoxyflurane have clearly shown renal damage. Renal damage is very difficult to quantify from chronic fluoride exposure. Fluoride intoxication has been reported. Vichy water is prepared from Potomania, which is highly mineralized water, in which the amount of fluoride is 8. 5 ml/liter. Its main properties are fluoride in it. In addition, end-stage kidney failure is present in humans exposed to fluoride due to their younger age, long-term exposure to high concentrations of fluoride, and information on the relationship between fluoride intoxication and other causes of kidney failure.

CONCLUSION

Excessive intake of fluoride has harmful effects on health. An excessive amount of fluoride causes dental fluorosis, and skeletal fluorosis, skeletal fluorosis as well as many disorders in the human body, spinal pain, joint pain, back pain, joint stiffness, leg paralysis, headache, Lack of appetite, pain,tension in muscles, diarrhea or constipation, dryness of mouth, feeling tired, etc. Excess amount of fluoride has harmful effects not only on human health but also on the health of all living beings. Therefore, the prescribed limit of fluoride in water is 1.5 prescribed by WHO. Excess of fluoride in water has harmful effects. Due to continuous consumption of fluoridated water, a day comes when people suffer from fluorosis. Which further causes fluorosis paralysis in which people remain confined to bed. There are many ways to treat fluoride-contaminated water. Technical Processes Ion exchange, electro-dialysis, adsorption, reverse osmosis, nano-filtration, and chemical precipitation methods can be used to remove excess fluoride from water. Laboratory studies show that each method has its own limitations. Therefore, the process of treating water should be according to the local requirements because there are some methods that reduce the amount of fluoride in water to less than one.

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REFERENCE:

1. Tikki, M. A. (2014). Fluoride removal from water–a review. *Int J SciEng Res*, *5*, 515-519.
2. Bhatnagar, A., Kumar, E., &Sillanpää, M. (2011). Fluoride removal from water by adsorption—a review. *Chemical engineering journal*, *171*(3), 811-840.
3. Miretzky, P., &Cirelli, A. F. (2011). Fluoride removal from water by chitosan derivatives and composites: a review. *Journal of Fluorine Chemistry*, *132*(4), 231-240.
4. Chen, N., Zhang, Z., Feng, C., Sugiura, N., Li, M., & Chen, R. (2010). Fluoride removal from water by granular ceramic adsorption. *Journal of colloid and interface science*, *348*(2), 579-584.
5. Medicaments: A review. *Iranian Journal of basic medical sciences*, *20*(8), 841.
6. Cheng, J., Meng, X., Jing, C., &Hao, J. (2014). La3+-modified activated alumina for fluoride removal from water. *Journal of hazardous materials*, *278*, 343-349.
7. He, J., Yang, Y., Wu, Z., Xie, C., Zhang, K., Kong, L., & Liu, J. (2020). Review of fluoride removal from water environment by adsorption. *Journal of Environmental Chemical Engineering*, *8*(6), 104516.
8. Kong, L., Tian, Y., Pang, Z., Huang, X., Li, M., Yang, R., ...&Zuo, W. (2019). Synchronous phosphate and fluoride removal from water by 3D rice-like lanthanum-doped La@ MgAl nanocomposites. *Chemical Engineering Journal*, *371*, 893-902.
9. Long, H., Jin, Y., Lin, M., Sun, Y., Zhang, L., & Clinch, C. (2009). Fluoride toxicity in the male reproductive system. *Fluoride*, *42*(4), 260-76.
10. Ortiz-Perez, D., Rodríguez-Martínez, M., Martínez, F., Borja-Aburto, V. H., Castelo, J., Grimaldo, &Díaz-Barriga, F. (2003). Fluoride-induced disruption of reproductive hormones in men. *Environmental Research*, *93*(1), 20-30.

11. Li, M., Wang, J., Wu, P., Manthari, R. K., Zhao, Y., Li, W., & Wang, J. (2020). Self-recovery study of the adverse effects of fluoride on the small intestine: involvement of pyroptosis induced inflammation. *Science of the Total Environment*, *742*, 140533.
12. Yin, S., Song, C., Wu, H., Chen, X., & Zhang, Y. (2015). Adverse effects of high concentrations of fluoride on characteristics of the ovary and mature oocyte of the mouse. *PLoS One*, *10*(6), e0129594.
13. Srivastava, S., & Flora, S. J. S. (2020). Fluoride in drinking water and skeletal fluorosis: a review of the global impact. *Current environmental health reports*, *7*, 140-146.
14. Lantz, O., Jouvin, M. H., De Vernejoul, M. C., &Druet, P. (1987). Fluoride-induced chronic renal failure. *American Journal of Kidney Diseases*, *10*(2), 136-139.
15. Shashi, A., Singh, J. P., &Thapar, S. P. (2002). Toxic effects of fluoride on rabbit kidney. *Fluoride*, *35*(1), 38-50.
16. Habuda-Stanić, M., ErgovićRavančić, M., & Flanagan, A. (2014). A review on adsorption of fluoride from aqueous solution. *Materials*, *7*(9), 6317-6366.
17. Singh, G., Kumar, B., Sen, P. K., &Majumdar, J. (1999). Removal of fluoride from spent pot liner leachate using ion exchange. *Water Environment Research*, *71*(1), 36-42.
18. Waghmare, S. S., &Arfin, T. (2015). Fluoride removal from water by various techniques. *Int. J. Innov. Sci. Eng. Technol*, *2*(3), 560-571.