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Correlating Silica Content in Drinking Water with Kidney Failure in Telangana-A Basic Study

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ABSTRACT

Arogyasri data reveals that since 2007 nearly 19000 registered for kidney failure out of which 7000 are living as on today. As it is well known fact that most of the physical ailments are because of the drinking water. It is pertinent to correlate the presence of silica; one of the responsible factors for kidney failure, in drinking water. The solid crust of the earth contains 80% to 90% silicates or other compounds of silicon. Water passing through or over the earth dissolves silica from sands, rocks and minerals as one of the impurities it collects. The silica content in natural waters is commonly in the 5 to 25 mg L^{-1} range, although concentrations over 100mg L^{-1} occur in some areas. Water is filtered by kidneys in which nephron is the functional unit. pH of water should be 6.5 to 8.5 (the permissible limits of pH according to BIS standards). Renal failure is mainly because of the pressure created in the glomerulus. There are different areas where kidney problems are prevalent. The aim of this project is to select drinking water from the epidemic areas of kidney failure and correlate with the silica content in it. Thorough review of literature is done to get assistance from earlier findings. This project is objected to prove that silica present in drinking water is also one of the reasons for kidney failure of the people in those areas.

Keywords: Drinking water, Silica, Glomerulonephritis.

INTRODUCTION

Silicon is next to oxygen in abundance in the earth's crust. It appears as the oxide (silica) in quartz and sand and is combined with metals in the form of many complex silicate minerals, particularly igneous rocks. Degradation of silica-containing rocks results in the presence of silica in natural waters as suspended particles, in a colloidal or polymeric state, and as silicic acids or silicate ions. Volcanic and geothermally heated waters often contain an abundance of silica. The silica (SiO_2) content of natural water most commonly is in the 1-30 mg per liter range, although concentration as high as 100 mg per liter are not unusual and concentrations exceeding 1000 mg per liter are found in Brackish waters and brines.

Silica in water is undesirable for a number of industrial uses because it is difficult to remove silica and silicate scales in equipment particularly on high pressure steam turbine blades. Silica is removed most often by using strongly basic anion exchange resins in the deionization process by distillation or reverse osmosis.

Safe water (Potable drinking water): Following criteria must be fulfilled for defining safe water, It should be free from pathogens, It should not exceed prescribed mineral limits mentioned by Bureau of Indian standards, It should be colorless or odorless. Water can be treated by killing microbes. Chlorination is useful for killing microbes. Chlorine reacts with water and produces HOCl (Hypochlorous acid). Fluorine is highly reactive so cannot be used. Bromine is in liquid state and colored, Iodine exists in solid and vapour state only. So, chlorine is manageable for disinfecting water.

Glomerulonephritis: Water is filtered by kidneys in which nephron is the functional unit. pH of water should be 6.5 to 8.5 (the permissible limits of pH according to BIS standards). Renal failure is mainly because of the pressure created in the glomerulus, the ultimate filtering area in a nephron by the accumulation of heavy metals like arsenic or by the accumulation of silica present in the drinking water. Kidney stops functioning by this silicosis in glomeruli. Even 95% damaged nephrons can be diagnosed as the healthy kidney as it is nature gift to manage the excretion even by remaining 5%. The process by which the kidneys clean blood (regulating its composition and volume) is called tubular secretion. This removes excessive quantities of certain dissolved substances from the body, and also maintains the blood at a normal healthy pH (which is typically in the range pH 7.35 to pH 7.45).

The substances that are secreted into the tubular fluid (for removal from the body) include: Potassium ions (K^+), Hydrogen ions (H^+), Ammonium ions (NH_4^+), Creatinine, Urea, Some hormones and some drugs (e.g. penicillin).

Tubular secretion occurs from the epithelial cells that line the renal tubules and collecting ducts. It is the tubular secretion of H^+ and NH_4^+ from the blood into the tubular fluid (i.e. urine - which is then excreted from the body via the ureter, bladder, and urethra) that helps to keep blood pH at its normal level. The movement of these ions also helps to conserve sodium bicarbonate ($NaHCO_3$). The typical pH of urine is about 6. When silica gets accumulated in the sieves of glomerule leads to kidney failure called as Glomerulonephritis.

Different areas where kidney problems are prevalent: Mining areas of Kothagudem, Agency area of Adilabad, Jogulamba Gadwal District, Patcharla, Venkatapuram, Yapadinna, Gudidoddi, Jeddoddi, Uppala, Aija

Nalgonda: Kanagal, Ragigudda, Repaka Devulapalli, Peethamparthi, Guwwalagutta

Occupational industries in which workers may be exposed to silica include (but are not limited to) agriculture, agricultural chemicals, asphalt and roofing, automobile repair, ceramics and pottery, construction, dentistry, and mining [1]. Recent reports suggest that between 1-3 million people in the United States work in occupational environments with potential exposure to silica and at least 10% of these workers may have dangerously high exposures (at least 2-10 times the recommended exposure limit) [2]. Prior research suggests that silica exposure is associated not only with silicosis, lung disease [3], rheumatoid arthritis [4], small vessel vasculitis [5] and other autoimmune diseases [6], but also with kidney damage [6-12]. The mechanisms by which silica may damage the renal system can be either through direct (silica particles in the kidney) or indirect toxicity [13]. This indirect toxicity likely occurs when the lungs, after being exposed to silica particles, begin to produce macrophages to attack the particles. This process, in addition to lymph node stimulation, activates the immune system and can lead to glomerulonephritis [14].

The global End Stage Renal Disease (ESRD) patient population continues to grow at an alarming rate due to a number of factors. The etiology of chronic kidney disease sited in Indian studies was chronic interstitial nephritis apart from diabetes and hypertension [15-20]). Chronic interstitial nephritis is presumed to be due to drugs or environmental toxins, and the possible environmental toxins include water and food related toxins [21]. It has been documented that environmental and occupational exposure to lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), arsenic (As), silica (SiO_2), strontium (Sr) and organic solvents, may lead to Chronic kidney disease (CKD) [22, 23]. The surface water sources like ponds, lakes and shallow wells were the traditional water drinking water sources in rural India [23]. However, the ever growing population and green revolution resulted in the imbalance of water sources at villages [24]. This lead to increased dependence on groundwater for irrigation and drinking needs and the groundwater is the only source of drinking water in entire rural and most parts of urban India [23].

Seepage of earth's crust elements such as silicon, strontium, heavy metals etc., into drinking water is a cause of concern. Silicon (Si), exists as silica (SiO_2) in nature and has been identified as environmental nephrotoxic (8). Over decades, epidemiological studies documented a strong association between exposure to silica and kidney disease (25-27). In addition, experimental studies on animals have also shown that high levels of SiO_2 in drinking water cause kidney disease [28]. Similarly, it was also reported that inhalation of silica dust during the mining process leads to the development of nephropathy [26]. The etiology of chronic kidney disease (CKD) is multi-factorial, among which exposure to certain heavy metals, organic solvents and trace elements such as Si and Sr are well known factors [29-34]. .

The aim of this project is to select drinking water from the epidemic areas of kidney failure and correlate with the silica content in it. Thorough review of literature is done to get assistance from earlier findings. This project is objected to prove that silica present in drinking water is also one of the reasons for kidney failure of the people in those areas.

Arogyasri data reveals that since 2007 nearly 19000 registered for kidney failure out of which 7000 are living as on today. This data had created alarm in the state government to establish dialysis centers in various districts of Telangana. As it is well known fact that most of the physical ailments are because of the drinking water. it is pertinent to correlate the presence of silica, one of the responsible factor for kidney failure, in drinking water.

MATERIALS AND METHODS

Ammonium Molybdate Method: At pH approximately 1.2 ammonium molybdate reacts with silica and any phosphate present to produce heteropolyacids. Oxalic acid is added to destroy the molybdophosphoric acid but not molybdosilicic acid. Even if phosphate is known to be absent, the addition of oxalic acid is highly desirable and is mandatory step in this method. The intensity of the yellow colour is proportional to the concentration of 'molybdate reactive' silica. In at least one of its forms, silica does not react with molybdate even though it is passed through the filter paper and is not noticeably turbid. it is not known to what extent such 'unreactive' occurs in waters. 'Molybdate reactive' silica can be converted to the reactive form by heating or fusing with alkali.

Because both apparatus and reagents may contribute silica, avoid using glassware as much as possible and use reagents low in silica. Also make a blank determination to correct for silica to be introduced. Treatment with oxalic acid eliminates interference from phosphate and decreases interference from tannin. If necessary, use photometric compensation to cancel interference from color and turbidity.

Minimum Desirable concentration: Approximately 1 mg SiO_2 L^{-1} can be detected in 50 mL, Nessler's tubes. Platinum dishes: 100 Ml, Colorimetric equipment spectrophotometer or a filter photometer is required. Nessler's tubes, matched, 50 mL, tall form.

Reagents: All reagents must be stored in plastic containers, Sodium bicarbonate, Sulfuric acid, Hydrochloric acid, Ammonium molybdate reagent. Dissolve 10g $(NH_4)_2Mo_7O_{24}.4H_2O$ in distilled water, with stirring and gentle warming, and dilute to 100 mL, filter if necessary. Adjust to pH 7 to 8 with silica for NH_4OH or NaOH and store in polyethylene bottle to stabilize. (If the pH is not adjusted, a precipitate gradually forms. if the solution is formed in glass, silica may leach out and cause high blanks). If necessary, prepare silica free NH_4OH by

Color development: To 50 mL sample add in rapid succession. Mix by inverting at least six times. Add 2.0 mL oxalic acid solution and mix thoroughly. Read color after 2 min but before 15 min, measuring time from addition of oxalic acid. Because the yellow color obeys Beer's law, measure photometrically or visually.

To detect the presence of molybdate-unreactive silica, digestion sample with $NaHCO_3$ before color development. This digestion is not necessarily sufficient to convert all molybdate- unreactive silica polymers may require extended under pressure for complete conversion. Omit digestion if all the silica is known to react with molybdate. Prepare a clear sample by filtration if necessary. Place 50 mL, or smaller portion diluted to 50 mL in a 100 mL platinum dish. Add 200 mg silica-free $NaHCO_3$ and digest on a steam bath for 1 h. Cool and add slowly, with stirring, 2.4 mL 1N H_2SO_4. Do not interrupt analysis but proceed at once with remaining steps. Transfer quantitatively to 50 mL nessler tube and make up to mark with distilled water. (Tall-form 50 mL nessler tubes transferred to an absorption cell for photometric measurement.)

Preparation of standards: If $NaHCO_3$ pretreatment is used, add to the standards (approximately 45 mL total volume) 200 slight amount of silica introduced by the reagents and for the effect of the salt on color intensity. Dilute to 50.0 mL.

Correction for color or turbidity: Prepare a special blank for every sample that needs such correction. Carry two identical portions of each sample through the procedure, including $NaHCO_3$ treatment if this is used. To one portion add all reagents. To other portion add HCl and oxalic acid but no molybdate. Adjust photometer to zero absorbance with the blank containing no molybdate before reading absorbance of molybdate treated sample.

Ammonium Molybdate Test for Silica (in brief): In HACH german make Colorimeter enter the programme for silica. Take 10 mL sample in two nessler tubes, one blank and another for test. Add the content of molybdate to the test sample. Add acid reagent to the test sample. Mix the reaction mixture. Press the timer and wait for 10 minutes, after 10 min add citric acid pillow. Enter the timer for two minutes, after two minutes take the readingsm, amount of silica is displayed on the colorimeter.

The water analysis laboratory at Institute for preventive medicine and discussed our project with Chief water analyst. He explained about the experimental part with respect to silica estimation and also directed us to NIMS for detailed discussion regarding correlation of silica with kidney failure at this lab different areas of kidney failures were identified and some samples brought from kothagudem area were analysed.

RESULTS AND DISCUSSION

Occupational industries in which workers may be exposed to silica include (but are not limited to) agriculture, agricultural chemicals, asphalt and roofing, automobile repair, ceramics and pottery, construction, dentistry and mining [1]. Our team was selected mining areas of Kothagudem for the study.

The mechanisms by which silica may damage the renal system can be either through direct (silica particles in the kidney) or indirect toxicity [13]. This indirect toxicity likely occurs when the lungs, after being exposed to silica particles, begin to produce macrophages to attack the particles. This process, in addition to lymph node stimulation, activates the immune system and can lead to glomerulonephritis [14]. The presence of silica in drinking water in sample selected from Kothagudem is found to be unsatisfactory and definitely it is one of the significant factors for Glomerulonephritis.

Table 1. Results of water samples collected from kothagudem mining area

S. No.	Source	Exact location	Colour	Turbidity	pH	Silica	Result
1	R.O water	Chunchupally Thanda, Kothagudem Dist.	<5	0.4	6.9	2.8	Satisfactory
2	Borewell	Main Road, Chunchupally Thanda, Kothagudem Dist.	<5	0.5	6.8	62	Unsatisfactory
3	Borewell	Bethampudi, Sujathanagar(M), Kothagudem Dist.	<5	0.3	7.1	68	Unsatisfactory
4	Borewell	Bethampudi, Koyagudem, Sujathanagar(M), Kothagudem Dist	<5	0.6	6.8	66	Unsatisfactory

The results show that drinking water from reverse osmosis is devoid of silica. But, in other selected mining areas of this project shows high level of silica content, resulting in kidney failures among these areas.

APPLICATION

This analysis technique can be applied to other areas, where kidney failures are prevalent, so as to conclude that silica is one of the responsible factor for kidney failures. In the selected areas of this project silica content in drinking water can be correlated with kidney failure in those areas. Alternate water sources like river water supply, RO water can be supplied to the affected areas. Rain water harvesting must be practiced in affected areas instead of ground water.

CONCLUSION

It is recommended that the state government should provide surface water for the drinking purpose in the region of where these problems are prevalent. Mission Bhageeratha, the state government prestigious project for drinking water supply is the panacea for all ailments linked to drinking water. It is the responsibility of the state to see that remote areas are also connected in this mission.

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