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A STUDY ON QUALITY ASSESSMENT OF BHOUMA JALA W.S.R. TO GROUND AND SURFACE WATER AROUND COAL BASED THERMAL POWER PLANT AT NANDIKUR, UDUPI DISTRICT, KARNATAKA

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ABSTRACT

Water is the most essential component of life and is vital for sustenance. There can be no state of positive health & well-being without safe water. In recent years, the global energy demand has increased with the advances in industrialization. Coal combustion from thermal power plants contributes to 55.32% of the total electricity generation in India. Major pollutants due to coal-based power generation include sulphur dioxide, carbon & nitrogen compounds, non-combustible hydrocarbons, heavy metals and fly ash. The methods of fly ash disposal result in metal contamination of surface and ground water resources. Heavy metals found in fly ash when mixed with water are hazardous for living organisms and they decrease primary productivity. Lack of safe and wholesome water supply affects health of the community. In Ayurveda, *jala* is given utmost importance in both health and disease conditions. When polluted, it results in *janapadodhwamsa* as *jala* is a common atmospheric factor upon which livelihood of the community depends. It is important to assess the quality of water before using it. One such attempt has been made through this study to assess the level of impurities present in surface and ground water sources around thermal power plant area. **Aims and Objectives: 1.** To study the different aspects of water conceptually in Ayurvedic perspective. 2. To assess the level of impurity present in ground and surface water sources in the vicinity of thermal power plant and compare with Ayurvedic and modern standards. **Methodology:** Water samples (1litre each) was freshly collected from well, bore well and tank at a distance of 1km, 2km

and 3km from the power plant area and taken to laboratory. Samples were subjected to physical, chemical & microbiological tests and compared with standard values (BIS: 10500-1993 standards), and the quality of water was assessed. Observation is compared with ayurvedic parameters of potable water such as- *nirgandha, avyakta rasa, shuchi, sheetala, accha, laghu, hridya*; and reasoning is drawn by Ayurvedic understanding. **Result:** The study showed that surface and ground water sources present at the proximity of thermal power plant were contaminated by indiscriminate disposal of fly ash and effluents. When compared with standards there was depletion in the water qualities like colour, odour, turbidity, hardness, conductivity, pH and TDS. Statistically significant results were shown in physico chemical parameters like dissolved oxygen, conductivity, pH and TDS values. Ayurvedic parameters of potable water was lacking in most of the samples. All samples were unfit for drinking and most of the samples were unsuitable for domestic use.

KEYWORDS: *Bhouma jala, jala guna, ground and surface water, water quality, thermal power plant.*

INTRODUCTION

Water is the most essential component of life and is vital for sustenance. It is a transparent, colourless, odourless and tasteless liquid when occurs in pure form. Water covers 71% of the Earth's surface. On Earth, 96.5% of the planet's crust water is found in seas and oceans, 1.7% in groundwater, 1.7% in glaciers & the icecaps, a small fraction in other large water bodies and 0.001% in the air as vapour, clouds and precipitation. Only 2.5% of it is freshwater, 98.8% is in ice and groundwater. A greater quantity of water is found in the Earth's interior.

Safe drinking water is essential to humans and other life-forms even though it provides no calories or organic nutrients. Drinking water, also known as potable water, is water safe enough for drinking, cooking and personal hygiene. Safe drinking water is water with physical, chemical and microbial characteristics that meet W.H.O. guidelines or national standards on drinking water quality.[1]

Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to adequate sanitation. Some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability. Much of the ill-health which affects humanity, especially in the developing countries can be traced to lack of safe and wholesome water supply. A report

issued in November 2009, suggests that by 2030 in some developing regions of the world, water demand will exceed supply by 50%. There can be no state of positive health & well-being without safe water. Safe drinking water is the basic element of *'primary health care'*.[2] In recent years, the global energy demand has increased with the advances in industrialization, and this has been largely met by fossil fuels. Coal meets 29.6% of global primary energy needs and its share in the world's electricity generation is about 42%. Coal combustion from thermal power plants contributes to 55.32% of the total electricity generation in India.[3] Major pollutants due to coal-based power generation include sulphur dioxide, carbon & nitrogen compounds, non-combustible hydrocarbons, heavy metals and fly ash. Major environmental problems associated with the use of coal in thermal power plant are likely contamination of air, water and land environment affecting the livelihood of the local people.

This study aims at the assessment of quality of Bhouma jala w.s.r. to ground and surface water, around the vicinity of coal based thermal power plant at Nandikur, Udupi district.

Prashasta Jala Lakshana **(Potable water)**

Nirgandha (odour less), *Avyakta rasa* (with unmanifest taste), *Trishnaghna* (quenches the thirst), *Shuchi* (clean), *Sheetala* (cool), *Achcha* (clear), *Laghu* (light) and *Hridya* (palatable/agreeable).[4]

Aprashasta Jala Lakshana **(Polluted water)**

Factors like *Keeta (poisonous insects like scorpion), Mootra (urine), Pureesha (faeces), Anda (eggs and spores), Shava (dead bodies of animals), Kotha (putrified matter), Trina (grass), Parna (leaves)* will contaminate water.[5]

In the context of *Janapadodhwamsa*, the main cause for the pollution of environmental factors is said to be *Adharma*. ***Vikrita Jala Lakshana*** is described by *Acharya Charaka* as- *Vikrita gandha-varna-rasa-sparsha, Kleda bahulam, Apakranta jalachara-vihangama, Upaksheena jaleshaya, Apagata guna.*[6]

Acharya Vagbhata in the context of *Viruddha prakarana* while explaining the cause of disease tells that when environmental factors (air, water, soil etc.) are vitiated the community will suffer from a disease even if wholesome regimen is followed. *Dushta jala* is an *ahita*

bhava in causing mass destruction because it is an unavoidable factor (*dushparihara*) which is used by people for cooking, drinking and other domestic purposes.[7]

Shat-dosha of Jala / Vyaapanna jala

Water which is covered by *panka* (mud), shaivala, *hatha* (*jalakumbhi*), *trina* (grasses), *padmapatra* (lotus leaves); which is not exposed to sunrays, moonrays and air and is associated with unpleasant smell, colour and taste- is known as '*vyaapanna jala' (*afflicted with *doshas)*. It develops six defects like.

- ***Sparsha dosha:*** *kharata* (roughness), *paicchilya* (sliminess), *oushnya* (hotness), *danta-grahita* (hypersensitivity of teeth)
- ***Roopa dosha:*** *panka-sikata-shaivala-bahu varnata* (unpleasant appearance)
- ***Rasa dosha:*** *vyakta-rasata* (manifest of taste/ defective taste)
- ***Gandha dosha:*** *anishta gandhata* (unpleasant smell)
- ***Veerya dosha:*** causes *trishna, gourava, shula, kapha-praseka* after ingestion
- ***Vipaka dosha:*** causes delay in digestion, *vishtambha* after ingestion.[8]

Thermal power plant

A thermal power plant is a power station in which heat energy is converted to electric power. The design of thermal power stations varies due to the different heat sources they make use of. Although nuclear heat energy and solar heat energy are in use, fossil fuel dominates in most cases. Coal combustion from thermal power plants contributes to 55.32% of the total electricity generation in India.

For the heat energy generation, coal is burnt in the boiler furnace, which results in the production of carbon dioxide and heat. The coal is first crushed into fine powder (size of 20mm) using a pulveriser. Fine powdered coal undergoes complete combustion and improves the efficiency of the boiler. The heat produced by the combustion of coal, boils the water in the boiler and steam is produced at a high temperature and pressure. The turbine in such power plant is generally steam-driven. The high-pressure steam produced in the boiler is directed to the turbine. The rotational energy imparted to the turbine rotates the generator rotor and produces electrical energy in the generator. The steam is then condensed in a condenser and pumped back into the boiler to repeat the cycle.

Major environmental problems associated with the use of coal in thermal power plant are likely contamination of air, water and land environment; because of large number of bi-

products produced during combustion of coal. Major pollutants due to coal-based power generation include sulphur dioxide, carbon & nitrogen compounds, non-combustible hydrocarbons, heavy metals and fly ash. If they are not properly treated before disposal or their indiscriminate methods of disposal result not only in environmental hazards, but also interfere with the livelihood of surrounding life forms very severely. Heavy metals are dangerous because once they enter the body of a living organism, increase in the concentration over time, faster than they are metabolised or excreted. Heavy metal toxicity can result in damaged or reduced mental and central nervous function, low energy levels, damage to blood composition, lungs, kidneys, liver and other vital organs. Long term exposure may result in slowly progressing physical, muscular and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy and multiple sclerosis. Long-term contact with some metals or their compounds may produce allergies and even cancer.

The fly ash is disposed of either by dry methods of disposal in landfills, or by wet methods of disposal where the ash is mixed with water and removed as slurry for settlement in ponds. Both these methods of fly ash disposal result in metal contamination of surface and groundwater resources, and hence can transfer these contaminants into the food chain. Heavy metals like arsenic, lead, nickel, cobalt, chromium, boron and antimony found in fly ash are hazardous for living organisms. Also, when such water mixes with a water body, it increases the turbidity of water body, thereby decreasing the primary productivity. This is harmful to the fisheries and other aquatic biota in the water body. Water is not only a vital environmental factor to all forms of life, but it has also a great role to play in socio-economic development of human population. Water quality depends on the local geology and ecosystem, as well as human uses, such as- sewage dispersion, industrial pollution, use of water bodies as a heat sink and overuse.[9]

Udupi Power Corporation Limited/ Adani Power Limited[10]

Udupi power corporation limited is a coal based thermal power station located in the village of Yellur, near Nandikur, Udupi district, Karnataka; established in 2008. It started with an instalment of two units of 600 MW capacity each, spread across 590 acres in Yellur and Santhuru villages. The plant became fully operational in September 2012.

Each unit has one sub critical coal fired steam generator connected to a reheat type condensing steam turbine and generator, with sea water cooled condenser and all other

required auxiliaries. Each steam turbine is of 3000 rpm, tandem compound, single re-heat, condensing type machine with extractions for regenerative feed-water heating. The turbine would be designed for main stream pressure of 170kg/cm^2 and inlet temperature of 537^{0}C. The UPCL supplied 90% of the power it generates to the State of Karnataka and 10% to the state of Punjab.

In April 2015, this power plant was sold to Adani power limited. Adani power limited is India's largest private sector power producer. It has expanded the power generation process to second phase by installing 2 units with the capacity of 800 MW each; with an aim of expanding its maximum output with an installed capacity of 20,000 MW by 2020.

Resource management

- ***Fuel***

- The coal is being imported from the coal companies in Indonesia, through International Competitive Bidding and spot purchases.
- The furnace oil is procured from the Indian Oil Companies depot in the region.

- ***Water***

- Sea water is used to meet the condenser cooling and other water requirements. Re-circulating type of circulating water system with natural draft cooling towers is installed.
- Desalination of sea water is carried out to meet freshwater requirement for the plant.
- The liquid effluents from the plant are being released to nearby streams.

- ***Ash***

- Bottom ash is collected in silos in moist form and fly ash is collected in dry form in storage silos.
- For the utilization of fly ash, agreement has been entered into with cement manufacturer.
- Unutilised ash is disposed at identified ash disposal areas.

Impact on surrounding environment

Methods of fly ash disposal and effluent disposal from the power plant is found to be harmful to the local environment. With the progression in time different problems have been reported due to pollution of air, water and soil.

News report[11]

A news report (February, 2011) about UPCL fly ash disposal near Padubidri says.

"The ash rises to the sky in thick clouds frequently when the wind blows, and the pollution and other problems created by fly ash have turned hazardous for the people living around the area. The coal ash that is being collected here contains harmful substances like carbon dioxide, phosphorous, lead and mercury. The environment, bushes, plants, trees, ground, water and air are getting polluted. The weak and elderly people are suffering from asthma and other problems, houses are covered under thick blanket of ash, wells have been polluted and agriculture has suffered irreversibly. The medical officer of nearby PHC says that the incidence of health complications like skin diseases, allergy, cough, itching, breathlessness has seen an increase in recent days.".

Fig 1: Fly ash disposal in landfills (dry method).

Fig 2: Tank water at 1km distance from thermal power plant area.

Fig 3: Dried fields with ash deposition on surface area.

MATERIALS AND METHODS

Source of sample

Water samples were freshly collected during summer season (March-April), from well, bore well and tank water resources (1 litre each) - at 1km, 2km and 3km distance from the area around coal based thermal power plant at Nandikur, Udupi district.

Method of collection of data

A. Sample

Water samples (1l each) were freshly collected from well, bore well and tank at the distance of 1km, 2km and 3km from the power plant.

B. Inclusion criteria

1. Water is to be freshly collected.
2. Water should not be subjected to any purification methods.
3. Source of water sample collection must be under use.

C. Exclusion criteria

1. Water stored in containers.
2. Water subjected to purification methods earlier.
3. Sources of water with long term disuse.

D. Study design

Procedure

Water samples were freshly collected in airtight containers and taken to laboratory within 2 hours of collection. Samples were subjected to physical, chemical & microbiological tests and compared with standard values (BIS: 10500-1993 standards), and the quality of water was assessed.

E. Assessment Criteria

1. Physical parameters: Colour, Odour, Turbidity
2. Chemical parameters: pH, Conductivity, TDS, Salinity, Dissolved oxygen, Calcium, Magnesium, Total hardness, Total alkalinity, Carbonates, Bicarbonates
3. Microbiological parameters: E.coli, Aerobic microbial count.

F. Data Analysis

The physical, chemical, microbiological qualities of ground and surface water are assessed and compared with the standard values; and the level of impurity present in the sources of water around the thermal power plant is assessed.

OBSERVATION AND RESULTS

➢ **Table no. 1: Descriptive Statistics- Distance wise.**

Distance		N	Minimum	Maximum	Mean	Std. Deviation
1km	Distance	3	1.00	1.00	1.0000	.00000
	pH	3	6.65	8.20	7.3200	.79605
	Colour	3	.00	.00	.0000	.00000
	Odour	3	1.00	1.00	1.0000	.00000
	Conductivity	3	1.24	817.00	374.0800	412.37058
	TDS	3	.64	510.00	214.8800	264.13649
	Salinity	3	.10	.48	.3400	.20881
	Turbidity	3	3.30	19.00	11.1000	7.85048
	DO	3	7.70	7.90	7.8000	.10000
	Ca	3	12.00	96.00	58.6667	42.77071
	Mg	3	7.29	51.03	34.0200	23.43407
	Hardness	3	60.00	450.00	286.6667	202.56686
	Alkalinity	3	50.00	150.00	105.3333	50.84617
	Carbonates	3	30.00	90.00	63.2000	30.50770
	Bicarbonates	3	20.00	60.00	42.1333	20.33847
	Valid N (listwise)	3				
2km	Distance	3	2.00	2.00	2.0000	.00000
	pH	3	7.72	8.85	8.2833	.56501
	Colour	3	.00	.00	.0000	.00000
	Odour	3	1.00	1.00	1.0000	.00000

	Conductivity	3	65.57	121.00	95.1900	27.91072
	TDS	3	38.30	72.50	55.5000	17.10088
	Salinity	3	.03	.06	.0433	.01528
	Turbidity	3	.65	189.00	68.7167	104.46945
	DO	3	7.10	7.50	7.2667	.20817
	Ca	3	8.00	16.00	13.3333	4.61880
	Mg	3	2.43	7.29	4.0500	2.80592
	Hardness	3	30.00	70.00	43.3333	23.09401
	Alkalinity	3	44.00	334.00	164.6667	151.00110
	Carbonates	3	26.40	200.04	98.6800	90.39882
	Bicarbonates	3	17.60	133.60	65.8667	60.40044
	Valid N (listwise)	3				
3km	Distance	3	3.00	3.00	3.0000	.00000
	pH	3	7.25	8.11	7.5967	.45358
	Colour	3	.00	.00	.0000	.00000
	Odour	3	1.00	1.00	1.0000	.00000
	Conductivity	3	40.30	242.70	108.2000	116.48223
	TDS	3	29.70	136.50	69.2667	58.52900
	Salinity	3	.02	.12	.0567	.05508
	Turbidity	3	.15	.24	.2100	.05196
	DO	3	7.20	7.80	7.5000	.30000
	Ca	3	8.00	44.00	21.3333	19.73153
	Mg	3	4.86	9.72	6.4800	2.80592
	Hardness	3	40.00	150.00	80.0000	60.82763
	Alkalinity	3	44.00	250.00	117.3333	115.10575
	Carbonates	3	26.40	150.00	70.4000	69.06345
	Bicarbonates	3	17.60	100.00	46.9333	46.04230
	Valid N (listwise)	3				

➢ **Table no. 2: Descriptive Statistics- Sample wise.**

Sample		N	Minimum	Maximum	Mean	Std. Deviation
Well	Sample	3	1.00	1.00	1.0000	.00000
	Distance	3	1.00	3.00	2.0000	1.00000
	pH	3	8.11	8.85	8.3867	.40377
	Colour	3	.00	.00	.0000	.00000
	Odour	3	1.00	1.00	1.0000	.00000
	Conductivity	3	41.60	817.00	308.0567	440.92077
	TDS	3	38.30	510.00	196.6333	271.38851
	Salinity	3	.03	.44	.1667	.23671
	Turbidity	3	.24	3.30	1.3967	1.66103
	DO	3	7.50	7.90	7.6333	.23094
	Ca	3	8.00	68.00	29.3333	33.54599
	Mg	3	2.43	43.74	17.0100	23.18072
	Hardness	3	30.00	350.00	143.3333	179.25773
	Alkalinity	3	44.00	150.00	79.3333	61.19913
	Carbonates	3	26.40	90.00	47.6000	36.71948
	Bicarbonates	3	17.60	60.00	31.7333	24.47965
	Valid N (listwise)	3				

Tank	Sample	3	2.00	2.00	2.0000	.00000
	Distance	3	1.00	3.00	2.0000	1.00000
	pH	3	6.65	8.28	7.4533	.81525
	Colour	3	.00	.00	.0000	.00000
	Odour	3	1.00	1.00	1.0000	.00000
	Conductivity	3	1.24	99.00	46.8467	49.20771
	TDS	3	.64	55.70	28.6800	27.54417
	Salinity	3	.02	.48	.1800	.26000
	Turbidity	3	.15	19.00	11.8833	10.23796
	DO	3	7.10	7.80	7.5667	.40415
	Ca	3	8.00	96.00	40.0000	48.66210
	Mg	3	2.43	51.03	19.4400	27.38471
	Hardness	3	30.00	450.00	173.3333	239.65253
	Alkalinity	3	50.00	116.00	74.6667	36.01851
	Carbonates	3	30.00	69.60	44.8000	21.61111
	Bicarbonates	3	20.00	46.40	29.8667	14.40741
	Valid N (listwise)	3				
Borewell	Sample	3	3.00	3.00	3.0000	.00000
	Distance	3	1.00	3.00	2.0000	1.00000
	pH	3	7.11	7.72	7.3600	.31953
	Colour	3	.00	.00	.0000	.00000
	Odour	3	1.00	1.00	1.0000	.00000
	Conductivity	3	121.00	304.00	222.5667	93.14646
	TDS	3	72.50	136.50	114.3333	36.25029
	Salinity	3	.06	.12	.0933	.03055
	Turbidity	3	.24	189.00	66.7467	106.01110
	DO	3	7.20	7.70	7.3667	.28868
	Ca	3	12.00	44.00	24.0000	17.43560
	Mg	3	7.29	9.72	8.1000	1.40296
	Hardness	3	60.00	150.00	93.3333	49.32883
	Alkalinity	3	116.00	334.00	233.3333	109.95150
	Carbonates	3	69.60	200.04	139.8800	65.80622
	Bicarbonates	3	46.40	133.60	93.3333	43.98060
	Valid N (listwise)	3				

Descriptive analysis of ayurvedic parameters

- **Table No. 3: showing assessment of ayurvedic parameters.**

Distance	**1km**			**2km**			**3km**		
Samples	**Tank**	**Well**	**Borewell**	**Tank**	**Well**	**Borewell**	**Tank**	**Well**	**Borewell**
Nirgandha	-	-	-	-	-	-	-	-	-
Avyakta Rasa	-	-	-	-	+	-	+	+	-
Trishnaghna	-	-	-	-	+	-	-	+	-
Shuchi	-	-	-	-	-	-	-	-	-
Sheetala	+	+	+	+	+	+	+	+	+
Accha	-	-	+	-	+	-	+	+	+
Laghu	-	-	-	-	+	-	+	+	-
Hridya	-	-	-	-	+	-	-	+	-

DISCUSSION

- **Discussion on sources and qualities**

In this study water samples were collected from tadaaga (tank) and koupa (well and borewell) variety of sources. As per the literature taadaaga jala should possess qualities like *vatala, swadu, kashaya, katu paki* and koopa jala should be *kshara, pittala, shleshmaghna, deepana, laghu.* Their qualities were assessed based on Ayurvedic and modern parameters and compared.

- **Discussion on time of collection**

The ideal time for the collection of groundwater is early morning, as it will be in pure state. This is mentioned for water that is used for drinking purpose. In this study water samples were collected during day time between 10 am to 11.30 am, in the month of March and April. March and April months come under *Chaitra maasa* of *Vasanta rutu.* As per the literature, water qualities in *Vasanta rutu* are *Kashaya, madhura, ruksha.*

- **Discussion on Ayurvedic parameters of quality assessment**

While considering standards of potable water mention by Acharya Charaka, following analysis is applicable.

- ***Nirgandha*** (odour less)

All water samples had a disagreeable odour. This is against the *prashasta jala lakshana.* These water samples are not suitable for drinking purpose. *Gandha dosha* of *jala* indicates that water needs to be purified before its use.

- ***Avyakta rasa*** (with unmanifest taste)

Taste was not elicited during the experiment. But it was observed that cattle refrained from drinking water in the nearby area of power plant. Hence by *anumana*, a reasoning can be drawn that there may be some *vyakta rasata* (defective taste) in these water sources. Further experimental studies can be taken to assess the taste of water sources and can be validated scientifically.

- ***Trishnaghna*** (quenches the thirst)

Tank water was not used for drinking purpose. Well & borewell water from 1km and 2km were having metallic odour and was not used by residents for drinking purpose. Hence this parameter could not be tested. As livestock also refrained from consuming tank and well

water, it can be assumed that these water sources did not fulfil the quality of quenching thirst. Plantations also were also appeared dry and pale. As the distance increased, water was more acceptable by people.

- ***Shuchi*** (clean)

All water samples showed presence of microbial load and E. coli. Turbidity level was high in few samples. Few samples were discoloured, which indicated that cleanliness around the water sources was not appropriate.

- ***Sheetala*** (cool)

Temperature of water samples were found to be normal. They corresponded with local atmospheric temperature. As the samples were collected during mid-day, hence *shaityata* was not expected as much as it could be during early morning hours. Because it is mentioned that *shaityata* of *jala* would be maximum during dawn.

- ***Achcha*** (clear)

Most of the samples were turbid and two samples were discoloured. Hence, they cannot be considered as *accha*. They do not match with standards of potable water.\

- ***Laghu*** (light)

Few samples had more concentration of salts and were hard. This made these water samples unsuitable for drinking as well as domestic use. High TDS of water samples were also noted. By this we can consider that water might have attained *guruta*. They can be used after subjecting to suitable *prasadana* techniques to make them light.

- ***Hridya*** (palatable/agreeable)

Most of the samples were not used for drinking by both humans and cattle. It contained metallic odour and orange to yellow discolouration. This indicated that water which was available near power plant is not palatable.

- **Discussion on modern parameters of quality assessment**

- ***Colour***

Drinking water should be free from colour. In this study, all water samples were colourless except tank and well water samples collected at 1km distance. They were discoloured to orange to yellow. This may be due to rust in water, which is suggestive of presence of iron

and iron bacteria in water. Excessive iron concentration in water may be due to direct mixing of effluents, surface run off and settlement of fly ash in water bodies.

- ***Odour***

Drinking water should be free from odour. All water samples had an odour that was disagreeable. They possessed metallic odour. One of the reason behind causing odour to water is from contamination by chemicals. It may also contain harmful substances. Change in odour maybe because of mixing of effluents from power plant to nearby water sources. Fly ash that mixes with air could settle down in these water sources, which might have contained particles of various metals in it; and this might have imparted an odour to the water.

- ***pH***

Among different water sources which were collected for analysis, well water samples showed greater pH value; i.e., it was more alkaline in nature. Tank water sample which was collected within 1km vicinity of power plant area had lesser pH value (6.65) and further reduction in its pH value could turn it acidic. Although tank water carries a pH value within normal ranges of drinking water standards (6.5-8.5), pH levels less than 7 may cause severe corrosion of metals in the distribution pipes. Well water sample that was collected within 2km vicinity had pH value (8.85) beyond normal limits of drinking water, which makes it unfit for drinking. It is not palatable to people as well as livestock. pH analysis of water samples of well and borewell show statistically significant changes.

- ***Conductivity***

Conductivity depends on the amount of salts and inorganic contents present in water. All water samples collected within 1km vicinity of the target area had significantly high measures of electrical conductivity, irrespective of their source. By this it is understood that the deposition of supersaturated inorganic constituents on soil has either directly mixed or percolated into water bodies. The saline mist that gets released from the cooling towers, which is locally dispersed by the wind to the nearby localities even up to 2 km; might have resulted in the increase of conductivity. Conductivity analysis of water samples of borewell and tank show statistically significant changes.

- ***Total dissolved solids (TDS)***

TDS is a combined sum of all ion particles (smaller than 0.0002 cm); that includes all disassociated electrolytes and dissolved organic matter. TDS measurements are derived from

conductivity. TDS values of samples were found ranging from 29.7 to 510mg/L. Comparatively, water samples collected from 1km vicinity had greater TDS values, though bore well water samples showed a high TDS content irrespective of distance. This accounts for both, contamination of local surface water and ground water, from the coal washed water draining to the nearby streams or surface run off and salt deposits, which has enhanced the ionic concentrations of surface and ground water sources. This makes the water unpalatable and hard to be used for domestic purposes. TDS analysis of water samples of borewell and tank show statistically significant changes.

- ***Salinity***

Salinity is the total concentration of all dissolved salts in water. Salinity values of collected water samples were ranging from 0.02 to 0.48. They are considered to be normal.

- ***Turbidity***

Turbidity of water is caused due to increase in suspended particles. Drinking water should be free from turbidity. In this study, turbidity values of samples were found ranging from 0.15 to 189 NTU. Tank and bore well water samples collected from 1 and 2km area from the power plant show turbidity level beyond normal limits. High turbidity of tank water (within 1km distance- 19 NTU) is due to direct disposal of effluents and improper lining of ash pond. It was discoloured to orange colour. High level of turbidity of borewell water may be due to subsequent leaching to ground water resources. Well waters had turbidity values within acceptable range, by which it can be considered that it is fit for drinking (after assessing other parameters). Turbidity decreased with increasing distance from the power plant.

- ***Dissolved oxygen***

Dissolved oxygen analysis measures the amount of gaseous oxygen dissolved in aqueous solution. It should not exceed above 110% (13-14mg/l). Also, if it falls below 5mg/l it is dangerous to aquatic life. In the present study, DO levels of samples were found ranging from 7.1 to 7.9mg/l. They were within normal range. Comparatively borewell water had less DO concentration, irrespective of distance. The tank water sample at 2km vicinity was found to have least DO concentration among all samples collected. This may be due to increased temperature or effluent discharge. DO analysis of water samples at 1km and 2km shows statistically significant changes.

- ***Total hardness***

Hardness is the measure of dissolved minerals in water. Total hardness values of samples were found ranging from 30 to 450 mg/L. Tank and well water samples collected within 1km had hardness values beyond permissible limits. It may be due to mixing of effluents and fly ash which contain high concentration of ions. Remaining water samples had hardness values within normal range. Comparatively borewell water was harder.

- ***Calcium***

Calcium values of samples were found ranging from 8 to 96 mg/L. Tank water sample at 1km distance from power plant had calcium values above permissible range. It may be due to mixing of effluents and fly ash. It will increase the hardness of water, makes water unpalatable and difficult for domestic use. Remaining samples had calcium concentration within normal values.

- ***Magnesium***

Magnesium values of samples were found ranging from 2.43 to 51.03 mg/L. Tank and well water samples at 1km distance from power plant had magnesium values above permissible range. It may be due to mixing of effluents and fly ash. It will increase the overall hardness of water, makes water unpalatable and unsuitable for domestic use.

- ***Total alkalinity***

Alkalinity values of samples were found ranging from 44 to 334 mg/L. Borewell water samples at 2 and 3km distance had high alkalinity values. It may be due to excess of hydroxyl ions, phosphates and organic acids in water. High alkalinity imparts bitter taste. Other water samples had lower alkalinities because of acidic environment in soil systems.

- ***Carbonates***

Carbonates values of samples were found ranging from 30 to 200.4 mg/L. Well and borewell water samples had comparatively higher carbonate values, irrespective of their distance. Tank water sample from 2km vicinity also had higher carbonates concentration. It will contribute to overall hardness of water, making it unpalatable and unsuitable for domestic use.

- ***Bicarbonates***

Bicarbonates values of samples were found ranging from 17.6 to 133.6 mg/L. Borewell water samples had comparatively higher bicarbonate values, irrespective of their distance. Well

water sample from 1km vicinity also had higher bicarbonates concentration. It will contribute to overall hardness of water, making it unpalatable and unsuitable for domestic use.

- ***Microbial load***

Drinking water should not contain any form of pathogenic organism. At 1km distance from power plant, all water samples showed definite number of colonies in the culture media. At 2km distance, tank and well water samples showed indefinite number of colonies in the culture media. There was no microbial growth in borewell water samples. At 3km distance, tank and borewell water samples showed indefinite number of colonies in the culture media. There was definite number of colonies in well water sample. Tank and well water samples showed presence of *E. coli* organisms irrespective of their distance. There was no *E. coli* in bore well water samples. None of these water samples is fit for drinking unless suitable method of treatment is employed.

- **Statistical analysis**

The observational data was analysed statistically by applying unpaired t-test and statistical significance was assessed based on obtained p-value. Following data proved to be statistically significant.

- DO analysis of water samples at 1km and 2km.
- pH analysis of water samples of well and borewell.
- conductivity analysis of water samples of borewell and tank.
- TDS analysis of water samples of borewell and tank.

CONCLUSION

- The quality assessment of environmental factors becomes important in preventing various epidemiological outbreaks. Water quality assessment is one among such attempts in maintaining community health.
- Methods of water collection, guidelines for drinking, purification and conservation methods of water which are told in Ayurveda are relevant even in present era. They are scientific and timetested evidences which aim at safeguarding individual and community health.
- Steps should be taken to develop the techniques mentioned by our Acharyas to globalise Ayurveda. They are easy to adopt, cost effective and have good outcome.

- It was evident that pollution of water was maximum near the thermal power plant and level of impurity decreased with increasing distance. When compared with standards there was depletion in the water qualities like colour, odour, turbidity, hardness, conductivity, pH and TDS.
- Ayurvedic standards of potable water were not present in most of the water samples. These water sources require suitable treatment method before use.
- Statistically significant results were observed in DO analysis of water samples at 1km and 2km, pH analysis of water samples of well and borewell, conductivity analysis of water samples of borewell and tank, TDS analysis of water samples of borewell and tank.
- When we observe recent developments, there is every possibility of extension of pollution level beyond 3km distance in near future, due to expansion in project plan of power plant.

- **Water conservation**

The term conservation implies both, protection of water resources, and further building up the precious water reserves. The method of rain water collection explained by *Acharya Sushruta* is one of such techniques: A clean, white cloth should be spread on *harmya-tala* (open terrace of *dhavalagraha*- building painted white). The rain water fallen on a part of this cloth should be collected and stored appropriately. This shows the significance of conserving rain water. Ideologies for the construction of different water reserves like- *Vaapi –ishtikadibhih baddha sasopaana-teertha* (staired well) and *Koopa – mrittika-ishtikadibhih baddha asopana* (non-staired well) – show that sanitation and conservation of water was given priority by our ancestors. Different storage methods explained in Ayurvedic literature give guidelines to prevent water from any contamination.

Limitation of the study

- Sample size was small and parameters taken for assessment of water were limited.
- Heavy metal content assessment was not done.

Scope for further study

Similar study can be taken up by

- taking more number of samples
- considering other seasons
- considering parameters for testing heavy metal contamination

- extending area of study beyond 3km area from thermal power plant for better assessment of water quality.

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