Physicochemical Studies on Assessment of Ground Water Quality of Kota District

A

Thesis

Submitted to the

University of Kota, Kota

For the award of the degree of

DOCTOR OF PHILOSOPHY

In the Faculty of Science (Chemistry)

By

ANILESH KUMAR YADAV

Under Supervision of

Dr. K.K. Gupta

Vice Principal (Retired)

Govt. College Kota,

Kota, Rajasthan

&

Under Co-Supervision of

Dr. S. M. Nafees

Lecturer in Chemistry

P.G. Department of Chemistry

Kota, Rajasthan

Govt. College Kota,

2016

CERTIFICATE

This is to certify that, the thesis entitled **"Physicochemical Studies on Assessment of Ground Water Quality of Kota District"** submitted to the University of Kota, Kota for the award of the Degree of Doctor of Philosophy in the Faculty of Science by **Mr. Anilesh Kumar Yadav**, is the result of work carried out by him in the P.G. Department of Chemistry, Govt. College Kota, under our **supervision**. The results of this thesis have not been submitted for award of any other degree to this or any other University.

Date: Dec. 2016

Dr. K. K. Gupta
(Supervisor)
Vice Principal (Retired)
Govt. College Kota,
Kota, Rajasthan

Dr. S. M. Nafees
(Co-supervisor)
Lecturer in Chemistry
P.G. Department of Chemistry
Govt. College Kota,
Kota, Rajasthan

ACKNOWLEDGEMENTS

First of all, I wish to thank my supervisor **Dr. K. K. Gupta** (Head / Vice Principal, Govt. College Kota) for his valuable guidance and precious support to complete my research work. I am thankful to him for allowing me extra time to complete my research work.

I am very grateful to my co-supervisor **Dr. S.M. Nafees** (Lecturer, P.G. Department of Chemistry, Govt. College Kota) whose supervision helped me to finish my experimental as well as theoretical work.

My special thanks and deepest gratitude to **Dr. Kalpana** (Lecturer & Research Supervisor, P.G. Department of Chemistry, Govt. College Kota) for valuable guidance and encouragement to shaping up my thesis work.

I would like to express my sincere thanks to **Dr. Nitin Gupta** (Lecturer, P.G. Department of Chemistry, Govt. College Kota) for his instructive discussions and constant support.

I express my gratitude to Principal, Govt. College Kota and **Head**, P.G. Department of Chemistry, Govt. College Kota for all the necessary research facilities extended to me.

I wish to acknowledge my special appreciation to **Dr. Tejendra Kaur, Dr. Suman Sharma, Dr. Seema Agrawal, Dr. Krishan Rani, Dr. Mahendra Kumar Jain, Dr. Jagarti Agrawal, Dr. Jaywanti Punjwani, Miss Priya Bhardwaj and Mr. R. K. Dubey** for their kind help to make my work easy. I am thankful to entire staff, department of chemistry, Govt. College Kota, for their co-operation.

The research work has been greatly supported by my beloved family. I express my deepest gratitude to my father **(Mr. Vasudev Yadav)** and mother **(Mrs. Phoola Devi)** who has been a source of encouragement and inspiration for me. I am also

grateful to my beloved brothers **(Harikesh Yadav and Pravesh Yadav)** for their constant support and co-operation.

I wish to acknowledge the unconditional love, support and help of my wife **(Mrs. Anita Yadav**). One of the wonderful experiences that I lived through in this period was the birth of my daughter **(Aarna)**, who provided me additional energy and happiness in life.

I also thank **Mr. Gaurav Sharam** (Incharge of store) and **D.C. Nagpal** (Incharge of Library) for their co-operation.

Finally I would like to thank all friends and well-wishers **(Ashish Malav, Jaswant Singh, Nitesh Oswal, Inder Singh, Jagdish Kandera)** for their help and timely advise.

KOTA

DATED: Dec, 2016 **ANILESH KUMAR YADAV**

CONTENTS

CHAPTER 1

INTRODUCTION
AND
REVIEW OF THE LITERATURE

INTRODUCTION

Water is a most abundant physical substance and transparent liquid on earth. In water molecule two atoms hydrogen and one atom oxygen are present. Water is the foundation of all form of life. Water is an essential natural resource for life of human beings, plants and animals on water planet. All processes of life are directly or indirectly connected to water therefore human beings cannot survive much longer without water, as water plays a central and critical role for every cell and organ system in the human body to function properly. Water is responsible for every activity in human body. In developing countries safe and sufficient drinking water supply is a crucial issue in rural and in many urban areas[41]. In rural areas groundwater is a reliable and finite source of water. The most common sources of water for irrigation and various purposes are surface water and groundwater. Ground water and surface water are interconnected. The surface water is present in the form of oceans, rivers, lakes, ponds and streams on the earth's surface and the groundwater present below the earth's surface in porous soils and rocks.

Groundwater is a vital source of water throughout the world. Groundwater is extracted by a bore or a well. Groundwater is a fundamental component of the water resources for domestic, industries and drinking purpose. Groundwater is contaminated from waste disposal sites, animal waste, leaking underground storage tanks, industrial chemical waste by pesticides and fertilizers, used in broad agricultural lands. Contaminated groundwater can be unsuitable for various purposes and its remediation is difficult, time-consuming and expensive. It may be harmful for human health as well as Environ. Health[35]. Groundwater is polluted when it contain enough impurities to make it unfit for intended use. Groundwater contaminations may be natural or human induced. Human activity affects the natural composition of groundwater. Groundwater contamination occurs due to the presence of unwanted constituent, and impurity in the groundwater. Use of contaminated groundwater causes health hazards to people, therefore it is important to check the activities that affect the quality and quantity of groundwater. Groundwater is widely used as drinking purpose in rural area[152].

WATER

The properties of water make it suitable for human beings to survive in differing weather conditions. Water is characterized by complex anamolus properties that differentiate it from other substances. Water is the universal solvent due to its polar nature. It dissolves a large number of different chemical substances. Its properties are as follows:

Physical properties of Water:

Water has many unique physical properties. It exists in all three physical states of matter: solid, liquid, and gas at atmospheric temperatures & pressures. Water has a very high specific heat capacity and a high heat of vaporization. Both properties arise due to extensive hydrogen bonding between water molecules. Water's very high specific heat capacity is a good medium for spreading the earth's heat. Water has high density, which depends on the dissolved solids and temperature of the water. Water is physically unique because it is less dense as solid (ice) than as a liquid. The maximum density of liquid water occurs at 4ºC. Water has a high surface tension as compared to other liquids due to strong cohesion between molecules. Surface tension is responsible for capillary action, which allows water to move through the roots of plants. Water is the substance of which solid state can float on liquid state. Various properties of water like melting point, boiling point, viscosity, slow heating and cooling are result of intermolecular hydrogen bonding between water molecules. Water has high value of dielectric constant. Water also has an exceptionally high heat of vaporization. Water is able to dissolve most of gases like O_2, CO_2, N_2, H_2, SO_2 and NH_3.[167]

Chemical properties of Water:

Water has many unique characteristics that make it ideal for life. Water is the chemical substance with chemical formula H_2O and bent shape. Water is a liquid at room temperature due to hydrogen bonding. In the water molecule both hydrogen atoms create a positive electrical charge while the oxygen atom creates a negative charge, therefore water molecules is polar in nature. Water is thermally stable but at higher temperatures dissociate into hydrogen and oxygen gases.

Water can ionize itself to a very small extent but in pure water the amounts of hydronium ions and hydroxide ions are equal[192]. Hence pure water is neutral. Water is an amphoteric molecule it acts as acid as well as a base. Water oxidizes carbon to carbon monoxide behaving as an oxidizing agent while it reduces chlorine gas to hydrogen chloride acting as a reducing agent.

Biological properties of Water:

Water is the universal solvent because it dissolves wide range of substances than other common solvents[4]. Water works as transporting biotic molecule, bio minerals, hormones and vitamins to different parts of animal and plant bodies. Water is significant for all the metabolic reactions essential for life to take place in solution in the cytoplasm of living cells. Water molecules are adhesive due to polar nature and therefore water sticks to other polar substances. This allows water to move upwards through the xylem of plants against gravity. Water dissolves oxygen gas from air which is necessary for aquatic life.

MAJOR WATER COMPARTMENTS

Water compartments are a large area where water is stored. Water is stored in various global compartments. The major water compartments on earth are specified as follows:

1. **Oceans and seas:** The Ocean is a largest compartment of saline water that covers much of the Earth's surface. Oceans cover about 70% of the Earth's surface and the oceans contain roughly 97% of the Earth's liquid water. The Oceans and seas have great effect on the weather and temperature on earth. The Oceans moderate the Earth's temperature by absorbing incoming solar radiation. The biomass in the oceans is over the 4 billion Tons.

2. **Glaciers, Ice and Snow:**

   Glaciers are slow moving rivers of ice. It takes a long time to from a glacier. Glacial ice often appears blue when it becomes very dense.

Glacier's affect weather patterns, climate, and sea levels. Glacial ice is the largest reservoir of freshwater on Earth. Glaciers store about 75 percent of the world's total freshwater. Water in glaciers and ice caps is a small percentage of all water on the Earth.

3. Groundwater:

Groundwaters are the hidden reserves that are connected to the surface water. Percolation is a hydrologic process in which water moves downward from surface water to groundwater. Groundwater is the subsurface water that fully saturates pores or cracks in soils. An aquifer is a geologic formation that contains sufficient saturated permeable material to yield significant quantities of water. Water added to aquifers naturally as water infiltrates into the soil. Water can removed from aquifers by drilling wells. Aquifers have been extremely important for livestock, irrigating crops, and as a source of municipal water[181]. The area in an aquifer, below the water table is zone of saturation in which all pores and fractures are saturated with water. Cone of depression is one of the valleys in the water table (Fig. 1). Movement of contaminated water and dispersion within the aquifer spreads the pollutant over a larger area. Contamination of surface water in recharge zones and seepage of pollutants through wells has polluted many aquifers making aquifers unfit for uses[3].

4. Rivers and streams:

Rivers are essential not only to humans, but to all form of life on the earth. Rivers and streams help to shape the features of the Earth. They help to drain rainwater and provide habitats for many species of plants and animals. Rivers make up only about 0.2 percent of all the fresh water on Earth. Rivers and streams carry water, organisms and important gases to many areas. Rivers are providing the power for hydroelectric plants. Ultimately rivers and streams deposit that water in the ocean.

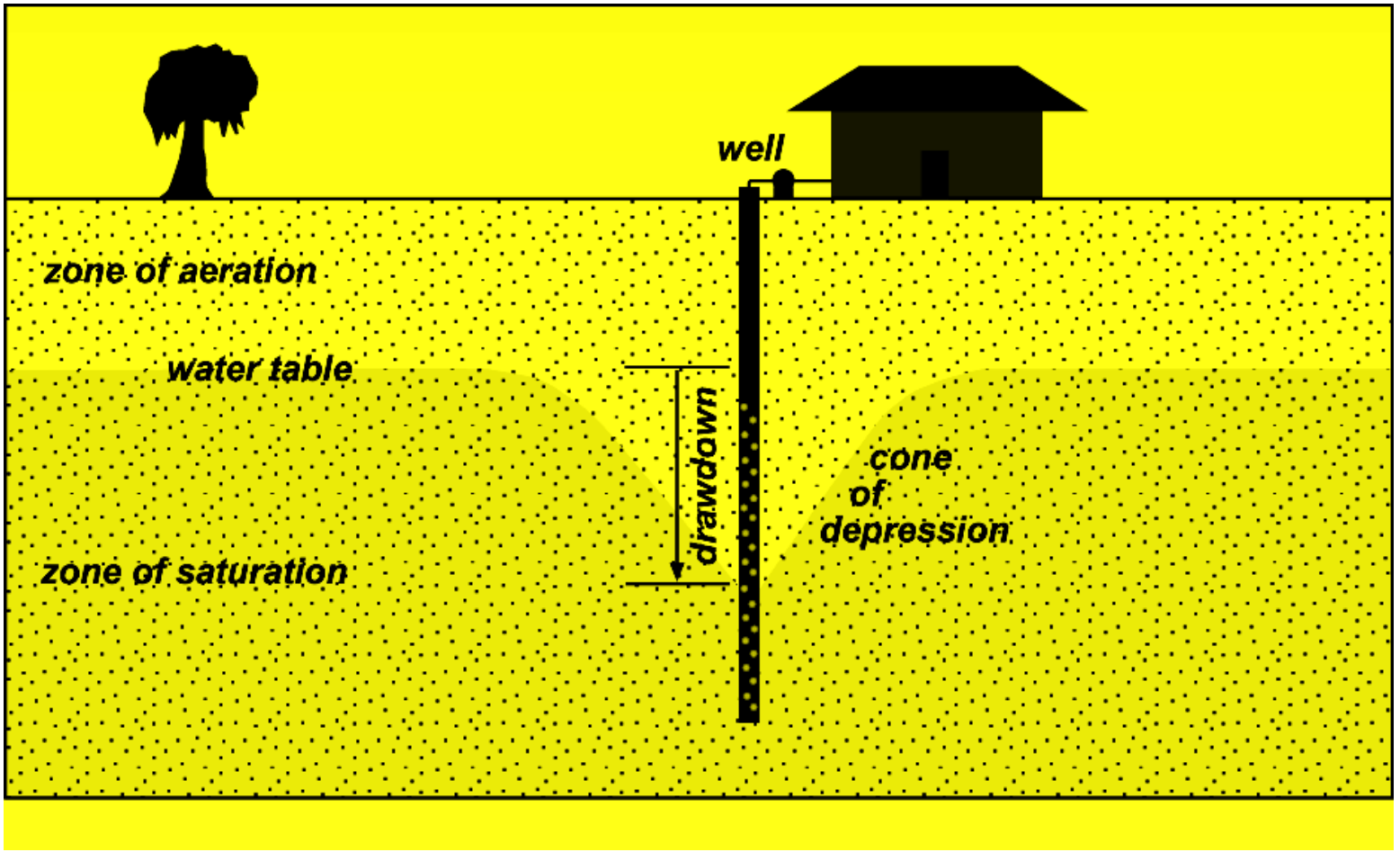

Fig. 1: Source of Groundwater: The area in an aquifer, below the water table is zone of saturation

5. **Springs:**

Spring is a natural situation where groundwater naturally emerges from the Earth's subsurface in a defined flow. Springs are the most obvious and interesting evidence of groundwater. Springs can discharge fresh groundwater into the beds of rivers or streams, and into the ocean. The temperature of spring water is related to the amount and rate of groundwater flow.

6. **Ponds and Lakes:**

A pond is a small area of fresh water. It is different from a river or a stream because it does not have moving water. The bottom of pond is usually covered with mud and Plants grow along the pond edge. Some ponds are formed naturally and some other ponds are man-made. Pond is a reservoir of rainwater. Pond is smaller than lake and lake is deeper than a pond.

Lakes are inland bodies of slowly moving water. Lakes are varied in terms of origin, occurrence, size, shape, depth and other features. Most lakes on Earth were formed by glacier activity. Lakes can be very deep or shallow. Lakes get water from precipitation, from rivers and streams and from underground water.

7. **Wetlands:**

Wetland is a place where the land is covered by water, either salty or fresh. These are some of the most productive habitats on the Earth. Wetlands are variable and dynamic water bodies where water covers the soil. They are freshwater, brackish or saline, inland or coastal, seasonal or permanent, natural or man-made. Wetlands are most important ecosystems to human survival and development. Wetlands are a critical part of our environment. They protect our shores to reduce the impacts of floods, absorb pollutants and improve water quality. Names of different type's wetlands are swamp, marsh and bog. Many animals use wetlands for all of their life-cycle. The most significant social and economic benefit that wetlands

provide is great volume of food. Human made wetlands are such as fish ponds, farm ponds, agricultural land, reservoirs, and canals.

8. **Atmosphere:**

   Atmosphere is the layer of gases that surrounds the Earth. The atmosphere is the smallest water reservoir of the earth. Water is located in the troposphere of the atmosphere. The water in the atmosphere presents only a very small percentage of the total water on Earth.

SIGNIFICANCE OF WATER

Water is the source of life and it is essential for all living forms and the environment health. It has the plentiful chemical substances on the Earth. It affects all form of life directly or indirectly[143]. The presence of water determines the location and activities of human on the earth. Water is a basic medium of metabolic functions in all life on earth. Water is used in every cell of body to transport nutrients, oxygen, and wastes to cells and organs. Water is a part of body's temperature regulating system. Water also plays an important role in the prevention of disease. Clean and freshwater must be free of contaminants to ensure wellness[93]. The quality of water is just as important as the quantity. Water is used for drinking, bathing, washing, sanitation, irrigation, air condition, power and steam generation, fisheries, ecology, recreation etc. water is widely used in production of atomic energy, chemicals, ice, paper, and steel. Water is the major component in the body required for all body functions such as respiration, perspiration, growth, digestion, waste elimination, reproduction and a host of other important activities. Water is a basic element of social and economic infrastructure. The consumptive and non-consumptive classifications of water are important. Water used consumptively reduce the source at the point of appropriation and is not available for other uses; whereas non-consumptive water use does not reduce the source and the water is available for further reuse[195].

HYDROLOGICAL CYCLE

The storage and movement of water between atmosphere, biosphere, lithosphere and the hydrosphere is the hydrological cycle. Water is stored on the earth as oceans, lakes, ponds, wetlands, in soils, rivers, as water vapor in atmosphere, as glaciers and groundwater. In the hydrological cycle, processes like evaporation, condensation, precipitation, deposition, runoff, infiltration, sublimation, transpiration, melting and groundwater flow occur[57]. The oceans water evaporated in the atmosphere and the maximum amount of evaporated water returned to the oceans by way of precipitation but remaining amount of evaporated water is transported to areas over landmasses where precipitation occurs by climatic conditions. Precipitated water moves as groundwater flow and runoff into rivers, lakes, ponds and oceans [59, 158]. The hydrological water cycle is a path way to transfer energy in between atmosphere and surface of the earth. Water is continuously cycled between various reservoirs (Fig. 2).

Evaporation:

The process by which water changes from a liquid to a gas is known as evaporation. Energy is required for evaporation that is used to break the bonds that hold water molecules together.

Transpiration:

The process by which plants return moisture to the air is known as transpiration. In transpiration plants lose some of the water through pores in their leaves. Transpiration is the evaporation of water into the atmosphere from leaves of plants. Transpiration accounts 10% of all evaporated water.

Condensation:

The cooling of water vapor until it becomes a liquid and turn directly into solid is known as condensation. In this process water vapor form tinny visible water droplets and these droplets are collect and form clouds.

Precipitation:

Precipitation is a process in which the moisture that falls from the atmosphere as rain, snow, sleet or hail. It varies in amount, and form by season and geographical location. The clouds will flow into streams or infiltrate into the ground.

Runoff:

The movement of water from precipitation across the earth's surface toward oceans is known as runoff. Rainfall duration, intensity and ground's slope affect the rate of runoff.

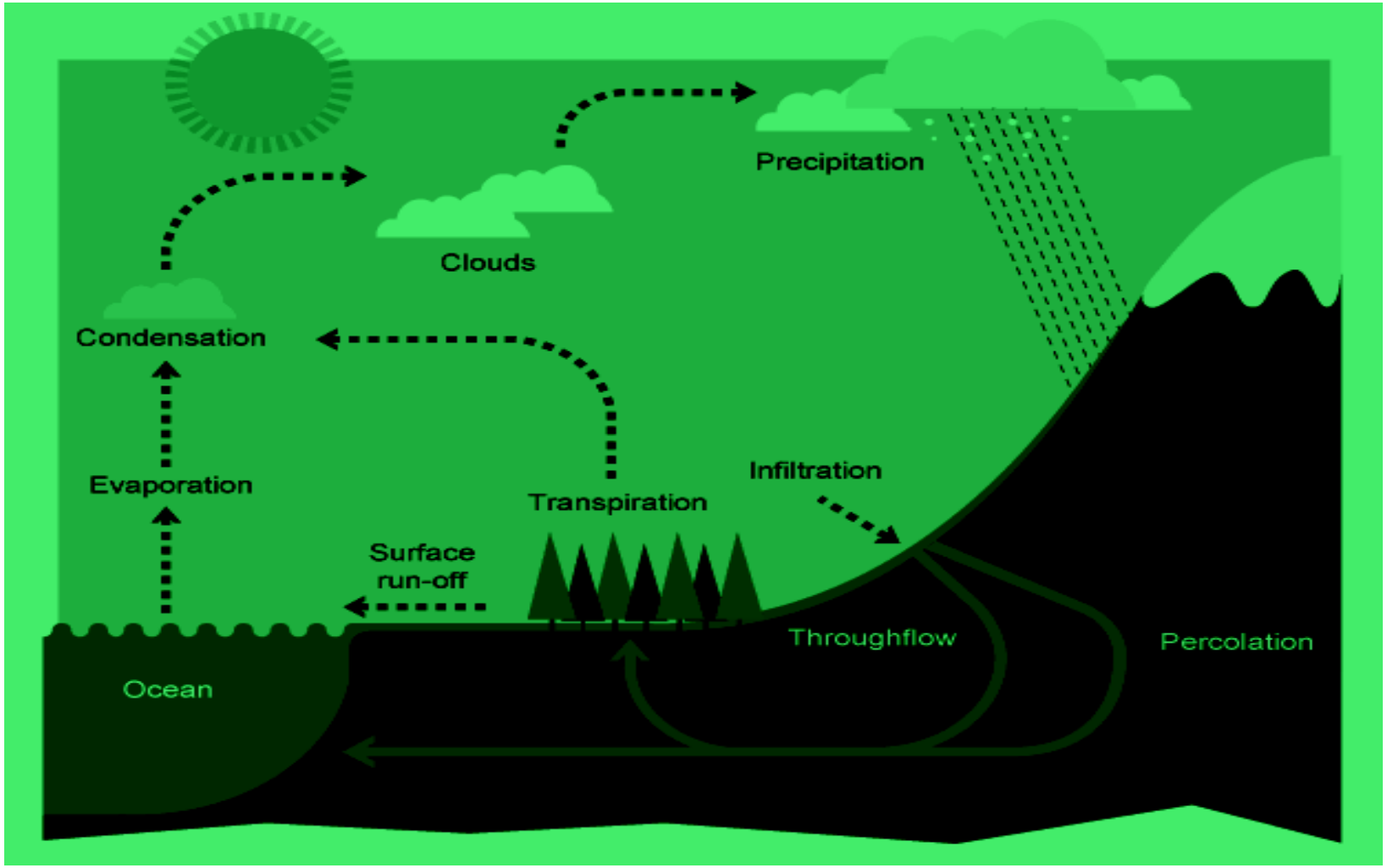

Fig. 2: The hydrological water cycle

Percolation:

The downward movement of water through soil, gravel and rocks until it reaches the water table is known as percolation. The terms infiltration and percolation are used interchangeably.

Groundwater:

Water that fills pores and fractures in the ground known as groundwater. The upper part of ground water is called the water table and between the water table and the land surface is the unsaturated zone. The water table is the level of water stands. (Fig. 3) The water table can be very close to the surface and very deep. In the unsaturated zone, water keeps moving downward to the water table to recharge the ground water[23, 65].

Groundwater

Groundwater is a hidden resource that saturates the tiny spaces between sand, gravel, silt, clay and fractures in rocks. Water in the soil is referred to as soil moisture and spaces between soil, gravel and rock are filled with water. Most groundwater is found in aquifers. Below the water table, soil and rocks are saturated with water[71]. Groundwater is stored in layers of soil, sand and rocks called aquifers. An aquifer is a layer of porous substrate that contains groundwater[28, 70].

Ground water moves from locations of higher pressure to locations of lower pressure. Groundwater movement in rock fractures is relatively slow, whereas it is relatively rapid in sand and gravels. Upper level of an underground surface in which the soil is permanently saturated with water is known as water table[184]. The water table is affected by climate change therefore it fluctuates both with the seasons and from year to year[73].

Most ground water moves relatively slow through rock underground because the flow of ground water is affected by water pressure and elevation, water within the upper part of the saturated zone tends to move downward. Water

rock pores are small then water moves slowly while when openings are large then the flow of water is more rapid. Spring is the place where water flows naturally from rock onto the land surface [66, 89]. Groundwater is recharged by the addition of water to the saturated zone. A deep hole that is dug or drilled into the ground to penetrate an aquifer is called well[74].

Groundwater contaminated by pesticides, herbicides, fertilizers that are applied to agricultural crops that can find their way into ground water when rain or irrigation water leaches the poisons downward into the soil[122]. Other pollutants like as city waste, household chemicals and heavy metals such as mercury, lead, chromium, copper, and cadmium can also leach by rain into groundwater. Groundwater can contaminate by liquid and solid wastes from sewage plants, septic tanks, and animal waste and slaughterhouses[124, 186, 197]. Radioactive waste can cause the pollution of ground water due to liquid radioactive wastes from the nuclear power industry Contaminated groundwater can be decontaminated by expensive long-term procedures. The groundwater quality must, in all cases, be controlled both before its use and during its use[8, 77].

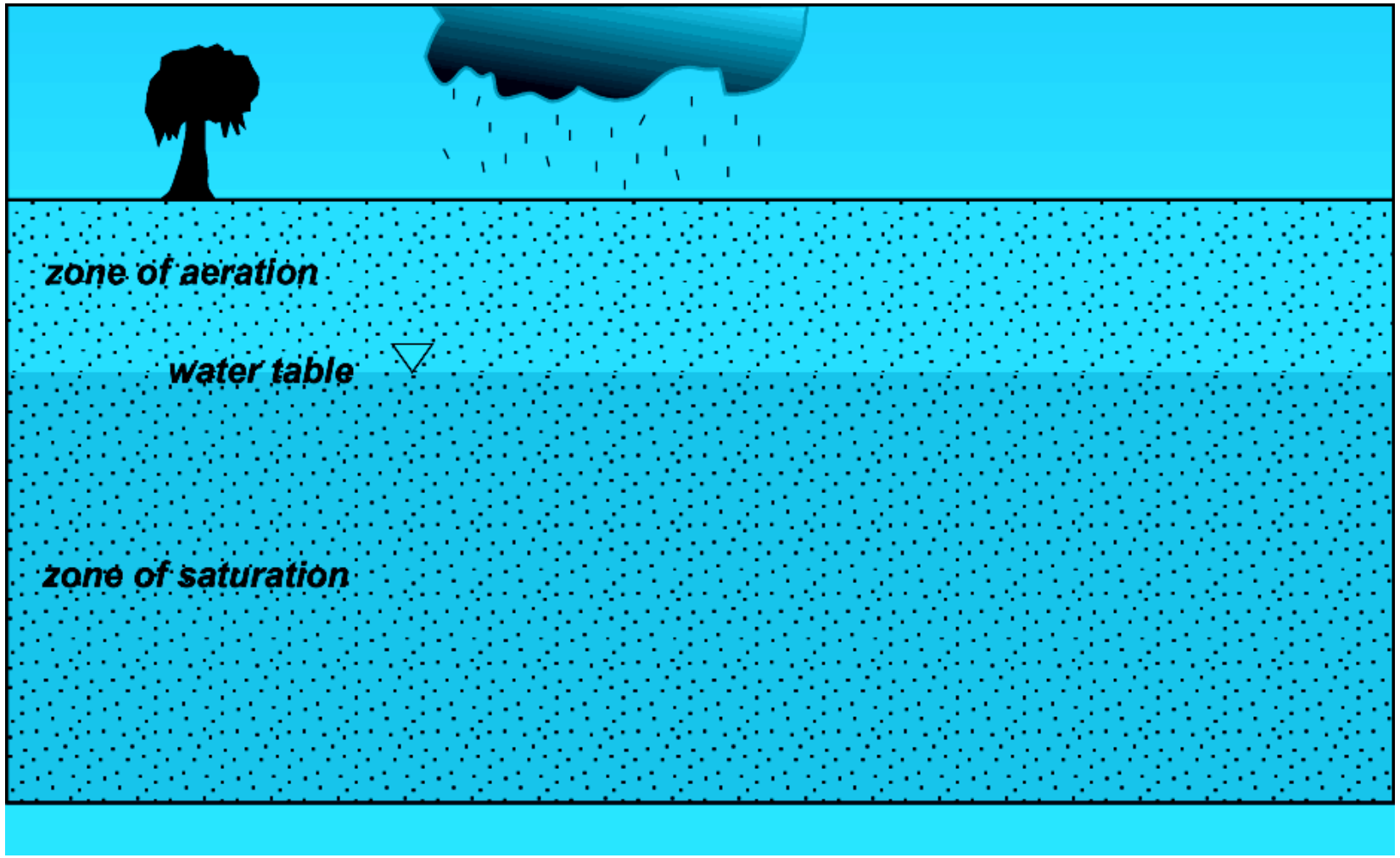

Fig. 3: The water table

GROUNDWATER QUALITY

Groundwater is an important natural resource of drinking water. The chemical and biological character of ground water is acceptable for most uses but the quality of ground water is changed as a result of man's activities[53, 78]. The natural quality of groundwater alters as groundwater flows from springs or rivers and recharge areas. Groundwater contains most common dissolved mineral substances such as sodium, potassium, magnesium, calcium, bicarbonate, chloride and sulfate.[160] The suitability of groundwater for various purposes depends on many factors such as dissolved minerals and organic substances present in ground water in different concentrations[86]. Some constituents are harmless, others are harmful, and a few may be highly toxic[79, 127]. Population growth is one of the major factors responsible for increased solid waste. Agriculture has wide impact on groundwater quality, where intensive practices take place[17]. Urbanisation and industrialisation have significant impact on groundwater quality. In many parts of earth atmospheric conditions also alter the quality of the groundwater. Groundwater is not considered desirable for drinking if the quantity of dissolved minerals exceeds from permissible limit[80, 81,198]. Groundwater in which dissolved minerals are present then its nature is saline. Dissolved minerals can be hazardous to animals and plants in large concentrations. Groundwater that contains a lot of calcium and magnesium is called hard water. The hardness of water is represented in terms of the amount of calcium carbonate[211, 101]. In recent years, the growth of industries, technology, and population has increased the stress upon water resources. The quality of groundwater has been degraded[96].

GROUNDWATER CONTAMINATION

Groundwater contamination occurs when man-made undesirable products get into the groundwater and cause it to become unsafe and unfit for human use. Serious health effects may be caused by contaminated groundwater. It has been assumed that contaminants can either be above or below ground [94, 85]. Movement of groundwater and dispersion within the aquifer spreads the contaminants over a wider area. Surface water percolate through soil then it picks up minerals, salt,

and organic compounds[6]. The water migrate downward therefore concentration of dissolved solids are increased[2]. In some areas minerals concentration is enough high so that the groundwater is unfit for drinking and irrigation purpose without treatment. When the contaminated water seeps into the soil and enters an aquifer it results into ground water contamination[105, 110]. Groundwater contamination comes from point and non-point sources. Point sources contamination comes from specific location such as septic system, underground storage tank and landfills but non-point sources contamination comes from a large area such as from agricultural waste (pesticides and fertilizers) and urban waste.

When the pollution originates from a single, identifiable source is known as a point source of contamination. Various types of point-source contaminants found in waters such as industrial, agricultural, and of urban sources. Point sources of pollution from agriculture may include animal waste storage and cleaning areas for pesticides, fertilizers. Municipal point sources include wastewater treatment plants, landfills[47]. Due to all of these activities, hazardous substance may include in the raw material. Non-point sources pollution occur over extensive areas. When water moves over and through the ground it can pick up natural contaminates, synthetic contaminates depositing them into rivers, wetlands, lakes and underground water[125]. Non-point sources contamination also occur by sediments, seepage of septic tanks and use of fertilizers. Irrigated agriculture is a significant source of groundwater non-point contamination.

Contamination of groundwater from septic tanks occurs under various conditions such as poor placement of septic leach fields, badly constructed percolation systems and high density placement of tanks[1]. If a septic system is not maintained properly then it can pollute drinking water[178]. A pollutants leak from sewer lines and sewage enter groundwater directly. Sewer leaks occur from soil slippage, seismic activity, sewage back up and loss of foundation. Residue of the chemical, biological, and physical treatment of municipal and industrial wastes is called sludge. Sludge contains organic matter, heavy matter and inorganic salts[201]. In recent years the quality of groundwater is degraded due to large production of

industrial and municipal waste[121]. Groundwater contamination occurs because the wastewaters migrate down to the aquifer[16].

SOURCES OF WATER POLLUTION

Ground water is located below the surface of the earth in spaces between rock and soil and it is a substantial source of water. Ground water contaminants occur by both natural and human activity[19]. The quality of groundwater is threatened by various sources of pollution, which are as follows.

(i) Industrial Effluents:

Industrial effluents contain various materials, depending on the industry such as chemical manufacturers, metal processers, steel plants, textile manufacturers. Industrial effluent consists of both organic substance and inorganic substances. The organic industrial effluents are produced by the industries such as pharmaceutical, organic dye, cosmetics, glue, soaps, synthetic detergents, herbicide, pesticide, textiles, paper plants[113], oil refining, metal processing and fermentation industries. The inorganic industrial effluents are produced mainly in the iron picking, electroplating plants, coal and steel industries[111]. Untreated industrial effluents caused the serious pollution problem to the ground water resources, human's life and an Environ. threat[169].

(ii) Agriculture Discharges:

Agriculture discharge occurs over a large area as non-point sources pollution, therefore its management and treatment is more difficult. Agricultural discharges contribute to degrade both ground and surface water[141]. Chemicals from fertilizers, pesticides, insecticides, farm waste, plants and animal debris, inorganic material and manure slurry are reported to cause huge pollution to surface and groundwater. Fertilizer pollution is difficult to regulate and reduce. It contains high levels of nitrogen and phosphorous with smaller amounts of potassium.

Nitrogen fertilizers containing nitrates can contaminate groundwater easily because nitrates are highly soluble in water. Rainwater runoff brings fertilizers into rivers, streams, lakes and oceans[49, 172].

(iii) Sewage and Domestic wastes:

Sewage is a significant source of water pollution. Sewage is the term used for wastewater that often contains domestic and industrial wastes. Sewage is commonly water that is discharged after home or industrial use. Sewage contains human waste, soap, detergent, glass, metals, garden waste and sewage sludge. Industrial sewage is used water from chemical processes while domestic sewage carries used water from houses. Untreated sewage may contain nitrogen, phosphorus, organic matter, bacteria, viruses, protozoa, oils, greases, mercury, cadmium, lead, chromium, copper and many toxic chemicals. Sewage released into the lakes, rivers and oceans cause a threat to human health.

(iv) Fertilizers:

Fertilizer isn't a problem if it is used carefully but too much use of fertilizer at the wrong time easily wash off into storm drains and then flow untreated into lakes or streams. A fertilizer is natural or synthetic material that supply one or more plant nutrients essential to the growth of plants. Fertilizers are artificial or organic materials they can cause serious problems. Fertilizers are used mainly in agricultural fields they contain high levels of nitrogen and phosphorus so they cause ecological problems. Nitrogen fertilizers contaminate groundwater which is poison to humans at high levels. Due to fertilizer pollution biggest change occurs in algae populations (Algal blooms). The excess fertilizer use runs off into waterways, they cause algae blooms [132].

(v) Runoff from Urban Areas:

Urban areas runoff created is a major source of water pollution in urban communities. In urban areas, water is often unable to infiltrate

into the soil as a result, urban runoff flows across roadways and urban landscapes. The pollutants from urban runoff include plant material, fertilizers, pesticides, and household chemicals waste. Urban runoff pollution is caused when the runoff, while traveling across the urban environment, acquires contaminants that affect water quality. Urban runoff pollution is nonpoint source pollution.

(vi) Organic Chemicals:

A number of organic chemicals are used in chemical industries. A very small amount of the chemicals that may reach drinking-water from various sources is a serious threat to human health[213].

Synthetic organic chemicals enter into the ecosystem through various human activities. Synthetic pesticides, food additives, synthetic detergents, pharmaceuticals, insecticides, synthetic fibers, plastics, solvents and volatile organic compounds are important sources of toxic organic chemicals in water.

(vii) Inorganic Pollutants:-

Inorganic pollutants such as mineral acids, trace elements, inorganic salts, metals, metal compounds, cyanides and sulphates are results of human activities and percolate in groundwater aquifers. Inorganic pollutants are non-biodegradable and persist in the environment[219]. Toxic inorganic materials adversely affect biological communities and aquatic ecosystem. Naturally occurring inorganic substance mainly contaminate groundwater.

(viii) Thermal Pollutants:

Thermal pollution is defined as sudden change in temperature of natural sources of water which may be lake, river and oceans by human influence. Manufacturing and Production plants are major source of thermal pollution. Discharge of hot water from nuclear

power plants, thermal power plants, and industries cause thermal pollution. The temperature of water body increases adversely affecting the aquatic animals such as fish, amphibians and other aquatic organisms. Thermal pollution can change the oxygen levels and affect local ecosystems and communities.

The warm temperature reduces the levels of Dissolved Oxygen in water. The warm water holds relatively less oxygen than cold water. Aquatic species are more sensitive to temperature changes because it causes significant changes in organism's metabolism and other biological changes. Thermal pollution increases the metabolic rate of organisms as increasing enzyme activity; therefore stability of food chain disrupts and alters the balance of species composition.

(ix) Radioactive Pollutants:

Radioactive waste has been created by humans as a co-product of various activities such as mining and refining of radioactive element, production and explosion of nuclear weapons, nuclear power plants, nuclear fuels and preparation of radioactive isotopes. Radioactive waste is a material that has been contaminated by radio nuclide. Radionuclide is unstable atoms of an element that decay emitting energy in the form of radiation.

Human activities produce large amount of radioactive elements into the environment. The radioactive materials are reaching into humans and animals body through food chains. The radioactive materials are reaching to water bodies where the aquatic species absorb them. Wastewaters containing these radioactive materials and they enter human body through food chains from wastewater. All organisms are affected by radiation pollution.

(x) Toxic Metals:

Toxic metals such as aluminum, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, may be harmful to human health including cardiovascular diseases, developmental abnormalities, neurologic and neurobehavioral disorders, diabetes, hearing loss, hematologic and immunologic disorders, and various types of cancer. Contamination of water resources by toxic metals occurs largely due to human activity. Toxic metals are widely distributed in the air, drinking water, food and elsewhere. Toxic Metals in water sources may occur naturally or may be the result of contamination. Naturally metals are dissolved in water when comes in contact with rock or soil. Other sources of metal contamination are leakage from waste disposal sites and corrosion of pipes[210].

HISTORICAL BACKGROUND OF KOTA DISTRICT

Knowledge of environment term is important to discuss Environ. pollution. Environment means surrounding and everything that affect an organism during its lifetime. In other words Environment is sum total of water, air and land interrelationships among themselves and also with the human being, other living organisms and property. In the following paragraphs, Environ. features of Kota district have been described.

1. LOCATION

Kota district is one of the Eastern districts of the state of Rajasthan in Western India. The district lies between 24º 25' and 25º 51' latitude and 75º 37' and 77 º 26’ longitudes. The district is bounded by Sawai Madhopur, Tonk and Bundi districts at North and North West. The Chambal River separates these districts and forms the natural boundary of Kota district. District is named after Kota town and is part of Kota Division. The maximum length of the district from North to South is 153 Kms and maximum width from East to West is 84 Kms. The total geographical area of the district is 521133 hectares as per land record. Kota district is shown in Fig.4 and the locations of sampling sites are also

illustrated in Fig. 4. Administratively the district includes 5 tehsils namely Digod, Itawa, Ladpura, Ramganjmandi and Sangod. Total numbers of villages in the district is 805 and it has 5 urban towns including 1 municipal corporation. The Kota district is bounded by Jhalawar, and Mandsor district of M.P. at the South, Baran district on the East and Chittorgarh district of Rajasthan on the West. According to 2011 census total pollution of Kota district was 1,951,014 in which 11, 76,604 is living in urban areas whereas 7,74,410 in rural area.

2. CLIMATE

The climate of the Kota district is generally semi-arid and arid with a long and hot summer, low rainfall and a short mild winter. The cold season start from December to February followed by hot season from March to June. After summers the rainy season starts with the onset of monsoon rains lasting till the end of September. The period September to November constitutes post monsoon period. January is the coldest month with mean daily maximum temperature at 24.3°C and a mean daily minimum temperature at 10.6°C. Mean daily maximum temperature during summers is 46.2°C and mean daily minimum temperature is 29.7°C.

3. GEMORPHOLOGY

Geomorphology can be describing the origin and development of landforms such as hills, valleys, sand dunes and caves. The district is characterized by several components such as landforms their nature and stability. Geomorphologic history helps in the proper evaluation of the configurations of the bedrock profile and surface material.

Kota district located in between Rivers Chambal, Kalisindh and Parbati. Consist of small, deep, narrow, depression, larger than gulley, smaller than gorges, usually carved by running water. Land cover of mainly marginal double crop, single crop, shallow and open scrub. Land cover is mainly forest and open scrub.

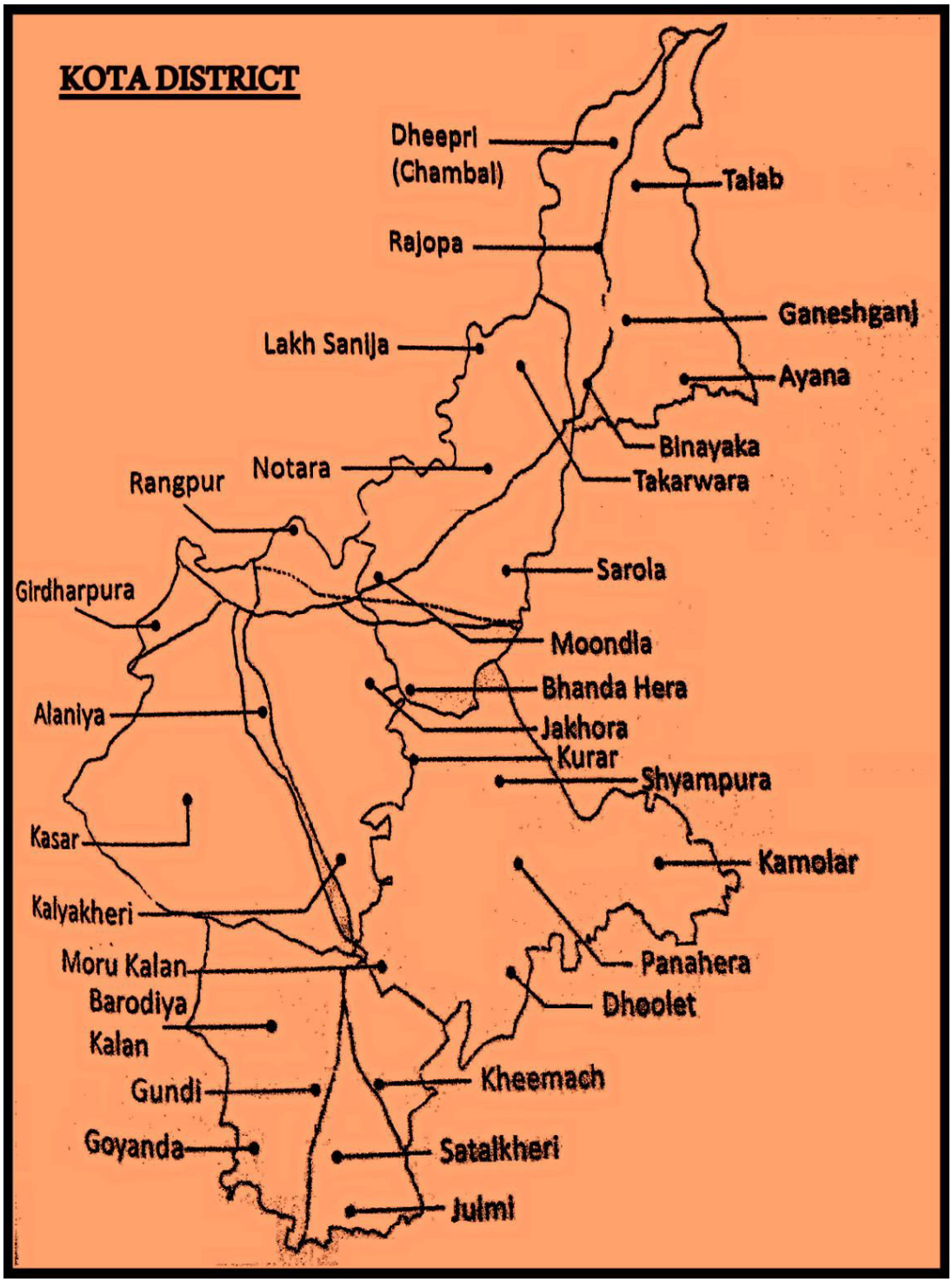

Fig. 4: Locations of sampling sites in Kota district

4. PHYSIOGRAPHY

Chambal is the main River in Kota district and Kalisindh, Paravan, Ujhar and Parvati etc. are Chambal's tributaries. Kota district land surface has a moderate slope from South to North. The hadoti area, of which Kota district is a section, has sheet rock, and also rich alluvial soil depleted via regular waterways. The quickened pace of siltation of riverbeds and stores is bringing on broad harm to watering system and also to agricultural generation framework. The zone requires quick activity to ensure the area and water assets. Floods are basic now a days and are likewise a reason for expansive measure of soil disintegration and destruction of vegetation, which thus are a reason for expanded floods.

5. SOIL TYPES

The soil of Kota is exceedingly variable, mirroring an assortment of parent materials, scope of conveyance of precipitation and its impact etc. All things considered diverse soils make distinctive sorts of living space for plant development, in this way, the genuine decision and afforestation designs on such sort of soils differ enormously. The mantle of alluvium around there is limited toward the North Eastern part. It is then on sandstone levels, where over substantial spread of bare rock, it is basically absent. Normally it is light topsoil, sandier over sandstone tracts and more clayey upon the shales. Dark cotton is pervasive on the Deccan trap. It is likewise found in patches lying upon the more established arrangements in spots where, it is assumed, trap was available similarly however has subsequent to been deteriorated. Everywhere throughout the forest area the soil are dry, ruined and inadequate in humus. On the inclines the soil is sandy to sandy-loam, shallow and secured with stones and rocks and are rosy in shading. It is for the most part shallow with outcrops of guardian rock.

6. VEGETATION

The vegetation of the Kota district fluctuates with its wide-ranging geology. The type of vegetation fluctuates with the accessibility of water. Interestingly some

confirmation affirms that Kota district was once loaded with rich green vegetation and had various streamlets going through the area. Near village settlements, in the midst of cultivable zones, are astounding forests, known as Radis, which are found in Bundi, Kota, Baran and Jhalwara state of Rajasthan. Radis are most regular in Kota. These Radis additionally have a "Devshtan" or a Temple, a lake, grazing ranges; memorial service spots and villagers are permitted to gather dead wood from these zones. Radis additionally yield fuel wood for building reason and branches leaves to fertilizer farmlands. Hadoti area of Rajasthan is all around developed with Babul (*Acacia nilotica*) trees. In these woods a wealth of the Babul and Khejada (*Acacia lecopholea*) is found. In uncommon case Sagwan (*Tectona grandish*) radi might likewise be found. Trees are developed in farmlands and home fenced in areas for grub, fuel wood, shade, products of the soil timber. Most extreme thickness of trees was found in Radis, and close habitations. Numerous studies have been done to look at the ethnoagroforestry in Kota district.

7. GROUDWATER FLOW

General course of groundwater stream compares to the surface drainage. In major parts of the zone, it has been gathered, Southwest to Northwest. However, in Eastern part around Sangod the stream heading is from South to North.

8. WATER LEVEL

In the study region, groundwater revive is mostly by rain water. In a decade ago rain fall pattern was changed and rather than typical rain, substantial precipitation in brief term happens. Significant part of the region, leaving aside pockets in Itawa, Sangod and Ramganjamandi Tehsil, has shallow water level less than 10 meter. Parts of Itawa tehsil along Chambal River and little area around Ramganjmandi and West of Sangod have profundity to water level between 10 to 20 meter ranges.

9. WATER LEVEL FLUCTUATION

The water level fluctuation map arranged on the basis of pre monsoon and post monsoon information. Southern part of the region including part of the Ladpura, Sangod and Ramganjmandi Tehsil show minimal consumption in water level under 2 meter. The map uncovers that in Itawa, Sultanpur and some portion of Ladpura tehsil along Chambal River and pockets in Sangod show ascend in water level inside of the scope of 0 to 4 meter. The problem area of the region where greatest consumption in water level measured is Sangod and the quality measured goes to 9.60 meters. Region around Sangod, Ramganjmadi promotion a pocket East of Ladpura show exhaustion in water level in the middle of 2 to 4 meters.

AIMS, OBJECTIVE AND SCOPE OF WORK

The decision of the issue to take up the investigation of Kota district has principally been founded on the essential perception that the groundwater has exhausted definitely because of over misuse to take care of the expanded demand because of urbanization and industrialization of Kota district. The groundwater assets have been draining at a disturbing rate as shown in a peeks declining at water levels. Groundwater quality deteriorated due to contamination of heavy metals, agrochemicals, organic pollutants and microbiological growth from tempest water, industrial effluents, and agricultural runoff and filtering from solid disposal sites. There are instance of water quality deterioration both common and additionally anthropogenic. The groundwater improvement has already surpassed the recommended levels of security and to take care of the expanding water demand some others sources need to recognize and some water resource management is expected to use the runoff water that for the most part goes as overflow.

Industrial, business and local necessity of water in Kota district is satisfied from River Chambal and waterway started from River Chambal, flood the greater part of the area around Kota district. Suburban and rural areas of Kota district are subject to groundwater to satisfy their need of water for drinking, domestic, recreational and at most area for agriculture. Major area of Kota district are

inherited by high value of pH, electrical conductivity, total broke down solids, Sodium, Nitrate, Fluoride and Residual sodium Carbonate. Present work is based on Kota district with all five tehsil.

Numerous administration bodies and NGO's are working yet at the same time there have been no desired results. This ought to make open revaluate about the issue and therefore about their wellbeing and riches. The research work is focused on the assessment of groundwater quality of Kota district and aimed description the reason for groundwater contamination and proposal for its therapeutic measure. The work is extensively classified with an attempt:

A. The current status of groundwater resources in Kota district based on the assessment of different tehsil.
B. Qualitative and quantitative characterization of groundwater resources and change during last three years.
C. Identification and outline of areas of chemically unsuitable water and quantitative assessment.
D. To propose the location for artificial recharge structure in urban and rural areas of Kota district.
E. To develop the most suitable reasonable arrangement and outline of artificial rainwater recharge structure on the basis of monitoring of constructed pilot structures.
F. To set up a groundwater management plan keeping in view the future interest.

A comparative investigation of data by correlation and computation analysis of various parameters of different location samples. Discussion on results so obtained in the light of pollution contamination status of the area and literature on public health aspects keeping in view geochemical viewpoints. To make public and responsible agencies know about the facts so that pollution control measures can be taken on time at various levels.

REVIEW OF THE LITERATURE

Water is abundant on our planet and it is essential for the survival of all form of life. The fresh water is a finite and limited resource[128, 29]. The aggregate sum of worldwide water, just 2.4% is appropriated on the fundamental land, of which just a small portion can be utilized as fresh water The accessible fresh water to man is hardly 0.3-0.5% of the aggregate water accessible on the earth and along these lines, its reasonable utilization is imperative[12]. Water is indispensable and one of the precious natural resources of this planet[168]. In addition to various domestic purposes, water is required for irrigation, power generation, sanitation and industries. To ensure safe groundwater for drinking in urban and rural areas, a multi faced and comprehensive approach is necessary. The cooperation of government, health staff, industrial management and the people is needed to preserve drinking water quality in our villages. With beginning of life in earth there was no pollution. Nature was in perfect balance. Issue of pollution began with civilization of man[35]. The demands of water supply have been increasing tremendously due to result of exploding population resulting in urbanization, industrialization, agriculture etc.

The concentration of salts depends upon the environment, and source of the ground water. The concentrations of dissolved constituents are found to be higher in groundwater than the surface waters. Polluted water used for drinking purposes leads to many diseases which are not water-borne but due to excess salts[162]. The quality and type of mineral matter dissolved in water depend on the physical structure and chemical composition of rocks. Industrial waste discharged into the aquatic system change the physicochemical properties of water such as hardness, conductivity, pH value, total dissolved solids (TDS), chemical oxygen demand (COD) and dissolved oxygen (DO) etc. Discharge of industrial effluents, domestic sewage and solid waste dump causes the groundwater to become contaminated and create health problems[136].

The expanding demand of water from fast growth of industries has put pressure on limited water resources[142]. Groundwater is extreme, most suitable fresh water resource with about adjusted concentration of the salt for human utilization[202]. The groundwater pollution is in particular area and there is no planned readymade arrangement. Industries serve as another originator of chemicals or groundwater contamination. The greater part of these sources of groundwater contamination is localized or non point sources such as solid waste disposal point, leakage from landfills, seepage from well and underground tanks disposal. The mining exercises are additionally a major role in groundwater contamination. Drainage from underground mines and filters from mine tailing contribute the same.

The significance and importance of groundwater has been all inclusive surely known by every one of the nations confronting the water related issues. In India with creating financial aspects, the ideal improvement, effective use furthermore, viable administration of their water assets ought to be the predominant technique for monetary development, yet in late year's unscientific administration and utilization of this assets for different reason practically perpetually has made undesirable issues afterward, water logging and saltiness in the instance of agribusiness utilize and environment contamination of different breaking points as an aftereffect of mining, businesses and city utilize[95]. In India, the greater part of the population is reliant on groundwater as the main source of drinking water supply. The groundwater is accepted to be comparatively much clean and free from contamination than surface water[130].

The quality of water can be influenced by various pollutants such as, chemical, biological and physical. Microorganisms, infections, substantial metals, nitrate and salt have discovered their way into water supplies[126]. The water contamination happens when a waterway is unfavorably influenced because of the expansion of a lot of materials to the water[15]. Ground water crisis is not the result of natural factors. It has been created by human activity quite a bit of sick well

being which impacts humankind, particularly in the developing nations can be followed to pool or traced to lake of safe and whole some water supply[177].

Ground water contains various ions and salts in high concentration, therefore using such type of water as drinking water then it leads to various water-borne diseases. Unsafe drinking water contributed to various health problems in developing countries for example, the one billion or more occurrences of diarrhea that happen yearly[104]. High concentration of chloride is due to the intrusion of domestic wastes and disposals by human activities. [84]. The changes in quality of groundwater response to variation in chemical, physical, and biological environments through which it passes [183, 208].

The usage of water from ages has prompted its over abuse combined with the developing population along with enhanced way of life as an outcome of technological innovations[205]. This contamination of groundwater is not far from the indecencies of modernization, therefore In this way, quality of groundwater is deteriorating at a speedier pace due to contamination extending from septic tanks [22], land fill leachates, domestic sewage [170, 193] agricultural runoff, agricultural fields [46, 72 137] and industrial wastes [156]. Reddy[155] have reported that the high concentration of iron in groundwater due to rusting of casing pipes, disposal of scrap iron in open areas, non-usage of bore wells for a long time, contamination due to industrial activities etc. The pH value of the water dependent upon the relative quantities of calcium, carbonates and bicarbonates[176].

Zafar[220] have carried out that the pH value of the water appears to be dependent upon the relative quantities of calcium, carbonates and bicarbonates. The water tends to be more alkaline when it possesses carbonates. The carbonate alkalinity was observed to be absent indicating that the total alkalinity recorded was due to accumulation of bicarbonate only[82, 207 159]. Fluoride in drinking water causes mild type of dental fluorosis[50, 69, 134 and 218]. Saralakumari[164] D. et al. reported that a significant part of the fluoride entering the human body is obtained from drinking water. Gopal[60] et al. have studied that fluoride samples which

exceeded the acceptable limit are not recommended for consumption without treatment. Fluoride is considered as an essential element though health problems may arise from either deficiency or excess amount[148, 31].

Naturally, chloride happens in a wide range of waters. The contribution of chloride in the groundwater is due to minerals like mica, apatite and hornblende and also from the liquid inclusions of igneous rocks [43, 52, 30]. Human excreta, especially the urine, contain chloride in an amount equal to the chlorides consumed with food and water increases the amount of chloride in municipal wastewater to about 15 mg/l above that of the carriage water in lotic systems[166]. The amount of the chloride present in the ground water samples was within the permissible limit. High chloride makes water salty in taste, which is unacceptable for human consumption [51, 54, 55]. Contamination of groundwater depends on the geology of the area and it is fast in hard rock where extensive cavern systems are below the water table[144, 182]. Rao[147] has point out that Groundwater chemistry has been used as a tool to outlook water quality for different purposes. Calculation of water quality index is an important technique for separating groundwater quality and its suitability for drinking purposes[201, 206].

WQI[102, 103 and 137, 185] is characterized as a method of rating that gives the composite impact of individual water quality parameters on the general quality of water for human utilization[108]. Shivasharanappa[173] et al. made investigation on assessment of ground water quality characteristics and Water Quality Index (WQI) of Bidar city and its industrial area, Karnataka State[200, 204.]

Ground water pollution[37, 145] by the heavy metals has turned into a striking issue for most recent two decades as consequences of release of industrial effluent, untreated domestic waste and increasing use of agrochemicals, i.e. fertilizers and pesticides in cultivation.

The water for utilization comes to people in various structures and from various sources. There have been two principle sources of drinking water; one is

surface water and other one is groundwater. In villages the main source of drinking water is groundwater available through hand pumps or bore wells[154]. Groundwater contamination in contrast to others is very critical, as a decentralized source of drinking water and other services for millions of rural and urban people, groundwater as a natural resource plays a crucial role which, accounts for nearly 80 per cent of the rural domestic water needs and 50 per cent of the urban water needs in India[97]. Higher Iron concentration in water causes staining on clothes and imparts bitter astringent taste[150].

Various research workers have carried out broad studies in the related field. Karunakaran K.[87] et al. have made statistical study on physicochemical characteristics of groundwater in and around Namakkal, Tamilnadu, India and suggested the necessity to purify the available water resource prior to utilization. Patil V. T. and Patil P. R.[130] carried out Physicochemical Analysis of selected groundwater samples of Amalner Town in Jalgaon District, Maharashtra, India and reported that the need of some treatment for minimization of the different parameters. Das G.[42] et al. have made assessment of drinking water quality of River Brahmani. Raja R. E. [136] et al. assessed the physico- chemical parameters of some groundwater samples of Kotputli Town Jaipur, Rajasthan.

Gupta N.[68] et al. have studied the physico-chemical analysis of drinking water quality from 32 locations in Delhi and reported that most of the water quality parameters slightly higher in the wet season than in the dry season. Drinking water is the major problem faced in the urban areas. Datta P. S.[48] et al. have carried out assessment of groundwater contamination from fertilizers in Delhi and reported that the conditions prevailing in the urban area make the water pullulated. Raja G. and Venkatesan P.[135] have studied groundwater pollution and its impact in and around Punnam Area of Karur District, Tamilnadu, India and reported that the water samples are highly polluted, hence suggested to exercise all the necessary precautions before the water is used for drinking and irrigation. Otherwise, it may lead to much adverse health effect. Shrivastava N.[174] et al. have made study of physicochemical characteristics of waterbodies around Jaipur that

Jalmahal lake and found most polluted having high alkalinity, free CO_2 , hardness and pH but a low level of DO, endosulfan and zinc contents in Jalmahal lake well also high, thus making it unsuitable for biota and fish and contrarily, Ramgarh lake shown high DO, low alkalinity, free CO_2 , hardness pH, endosulfan and zinc concentrations were relatively low throughout the year.

Craig, E. and Anderson M.P.[39] carried out study on the effects of urbanization on groundwater quality Ghosh, S.[58] et al. investigated assessment of health Risks associated with fluoride-contaminated groundwater in Birbhum district of West Bengal Dass,S.[45] et al. carried out a Study on Fluoride and other water quality parameters of ground water of district Agra (U.P.). Hemant P.[75] et al. reported study on seasonal variation in groundwater quality of Sagar city K Murli R. D.[117] et al. evaluated the ground water quality in Coimbatore South Taluk , Coimbatore district Loganathan D.[99] et al. investigated status of groundwater at Chennai city Keshvan. K.G. and Parameswari R.[91] made investigations on ground water quality in Kancheepuram. Belkhiri L.[24] et al. investigated groundwater quality and its suitability for drinking and for agricultural use in Ain Azel plain Algeria. Khaiwal R. and Garg V. K.[92] studied distribution of fluoride in groundwater and its suitability assessment for drinking purpose.

Mishra A.[106] et al. work out the comparative Study of physico- chemical and microbial parameters on Lotic and ground-waters in selected outlying areas of central Gujarat. Nagarajappa D. P.[119] et al. assessed physic-chemical analysis of underground water of Harihara taluk of Davanagere district, Karnataka. Mishra, P.C., and Patel, R.K.[107] have made study on the pollution load in the drinking water of Rairangpur, a small tribal dominated town of North Orissa. Mumtazuddin S.[116] et al. have carried out the physico-chemical analysis of groundwater of the Budhi Gandak belt in Muzaffarpur district. Mohrir A.[112] et al. reported surface and groundwater quality assessment in Bina region. Muthukumaravel K.[118] et al. have reported the evaluation of groundwater quality in Perambalur. Mohan R.[109] et al. have made investigations on Hydrochemistry and quality assessment of

groundwater in Naini Industrial Area, Allahabad district. Suman M.[114] et al. worked on assessment of ground water quality in Jind city.

Kaur R. and Singh R.V.[88] have made assessment for different groundwater quality parameters for irrigation purposes in Bikaner city, Rajasthan. Nosrat Aghadeh and Asghar Mogaddam[5] carried out assessment of groundwater quality and its suitability for drinking and agricultural uses in the Oshnavish Area, Northeast of Iran. Niranjan K.[123] et al. groundwater quality assessment of Wailpalli Nalgonda.

Patil N.[129] et al. made study on the physicochemical characteristics of ground water of Gulbarga city, Karnataka. Ravichandra R. and Chandana O. S.[151] evaluated groundwater pollution in Bakkannaplem, Visakhapatnam. Govt. P.G. College, Bina[131] made investigations on physico-chemical analysis of groundwater samples of sagar city with respect to water soluble pollutants. Ramakrishna C.[139] et al. Studied on groundwater quality in slums of Visakhapatnam. Rao R.[146] et al. carried out assessment of ground water quality for application in Kakinada. Rao[194] et al. carried out an assessment of quality of drinking water at srikurmam in Srikakulam District, Andhra Pradesh. Rao[147] et al. assessed ground water quality in a coastal area, Andhra Pradesh. Ratnakanth Babu M. J.[149] carried out on assessment of groundwater pollution in parts of Guntur District. Raviprakash S. and Rao G. K.[153] studied the chemistry of ground water in Paravada area with regard to their suitability for domestic and irrigational purposes. Gorde S.P. and Jadhav M.V.[61] carried out assessment of water quality parameters.

Mukherjee S.[115] et al. made work on assessment of groundwater quality in the South 24-parganas, West Bengal coast. Sabahi E. A. l.[161] et al. studied the characteristics of leachate and groundwater pollution at municipal solid waste landfill of Ibb city, Yemen. Saha D. et al.[163] made investigation on geochemical evolution of groundwater in the Pleistocene aquifers of South Ganga Plain, Bihar. Kumar S.[98] reported among water quality parameters for ground water in Barmer district. Sharma J. D.[171] et al. have studied quality status of groundwater of Sanganer tehsil in Jaipur district. Sawant R. S.[165] et al. studied groundwater

quality of Gadhinglaj Tehsil of Maharashtra. Singh A. and Choudhary S. K.[179] made studies on chemical analysis of groundwater of Nathnagar block under Bhagalpur district, Bihar. Singh A.K.[180] et al. evaluated hydrogeochemical processes and groundwater quality in the Jhansi district of Bundelkhand region. Somashekar R. K.[188] et al. evaluated the groundwater chemistry of Channapatna Taluk, Bangalore rural district. Subba Rao N.[196] studied the Environ. impact of industrial effluents on ground water in regions of Visakhapatnam Industrial Complex.

Suryanarayana K.[199] carried out effect of groundwater quality on health hazards in parts of Eastern ghats. Tiwari A.K. and Singh A.K.[203] carried out the hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh. Banerji A. K.[22] made investigation on importance of evolving a management plan for groundwater development in the Calcutta region of the Bengal basin. Naik S. and Purohit K. M.[120] reported Studies on water quality of river Brahmani in Sundargarh district, Orissa. Rao V. et al.[209] worked on factors controlling groundwater quality in parts of Srikakulam District, Andhra Pradesh.

Industrial effluents contain heavy metals which have long lasting adverse effects on human health. Today, heavy metals are as often as possible present in our water, soil and air because of broad utilization of their compounds[67]. Heavy metal pollution in groundwater causes major health effects on human beings. Banerjee S.[21] et al. reported heavy metal contaminants in underground water at Indo Bangla Border Districts of Tripura, India. Mohan[109] et al. studied heavy metals in the groundwater of non-industrial area. Mohapatra U. K. and Singh B. C. reported trace metals in drinking water from different sources in old capital city of Cuttak. Removal of zinc from wastewater by adsorption reported by Shrivastava[175] et al. preliminary studies on heavy metals in ground water of Mandeep has been carried out by Verma N.K.[210] et al.

In recent years the water resources are depleting at an alarming rate due to careless misuse, consequently need of water resource management and protection strategies are on prime interest [36, 38, 40, 190]. High concentration of fluoride in drinking water caused hazardous effects studied by many workers in different parts of India. Ashley R. P. and Burely M. J.[14] made investigation on controls on the occurrence of fluoride in the groundwater in the Rift Valley of Ethiopia. Banerjee A.[20] reported groundwater fluoride contamination. Ghosh S.[58] et al. carried out assessment of health risks associated with fluoride contaminated groundwater in Birbhum district of West Bengal.

In India most of the states are facing acute water shortage. In these states top priority is recharging the aquifers through rainwater harvesting. Scientists developed so many techniques and modeling for interpretation of water quality in terms of suitability for domestic, drinking, industrial and irrigation purpose. LSI, AI and RI[133] are the most popular among these all. Water quality data presented in terms of % Na, SAR, ESP and RSC shows the suitability of water for irrigation purpose. In recent years remote sensing and GIS[100] technology is developed to assess the water properties. Remote sensing data are well used in water resource evaluation and management.

Seasonal pollution assessment through comparative hydro biolological studies in river Jojari at Salawas, Jodhpur has been discussed by Vishoni S.R.[212] et al. Sinha D.K. and Saxena R.[187] worked on statistical assessment of underground drinking water contamination and effect of monsoon at Hasanpur, J.P. Nagar, Uttar Pradesh. Hemant P. and Limaye S.N.[76] made study of seasonal variation in groundwater quality of sagar city.

Saleem A.[2] et al. assessed correlation-regression model for physicochemical quality of groundwater in the South Ind. city of Gulbarga. Aravinda H.B.[13, 56,] studied correlation coefficient of some physico-chemical parameters of river Tungabhadra, Karnataka. Chandra Sekhar M. and Satya Prasad M. V. K.[34] regression models for assessment of dissolved pollutants in

Krishna River. Dash J. R. [44] et al. studied a correlation and regression study on the ground water quality in rural areas around Angul-Talcher industrial zone. Jeyaraj T.[83,] et al. reported correlation among water quality parameters for ground water samples of Bharathi Nagar of Tiruchirapalli City.

In context of Rajasthan and especially Hadoti region, water resource improvement has been recognized as one of the thurst area due to general deficiency of this resource and keeping the sound condition and accessibility of natural water resource for future use. Subsequently standard hydrological programmes have been completed by state and central government agencies such as Central Groundwater Board (CGWB), Ground Water Board (GWB), Command Area Development (CAD), [32, 33, 62 and 63] State Pollution Central Board (SPCB), Public Health Engineering Department (PHED) [10, 64]. Few research groups in Universities are additionally occupied with investigations in the field of hydrology and water contamination.

Literature overview reveals that no specific work has been done so far to evaluate the qualitative aspect of groundwater of Kota District for domestic, drinking, irrigation and industrial purpose. Thus present research work has under taken to investigate the physicochemical characteristics of groundwater of this area.

CHAPTER 2

METHODS
AND
METHODOLOGY

METHODS AND METHODOLOGY

This chapter describes the methods of sample collection and analytical procedure adopted for analysis of groundwater samples of Kota district using different analytical methods. To evaluate the impact of contaminants on groundwater of Kota district, water samples were collected from 30 different selected sites of five tehsil (Digod, Itawa, Ladpura, Ramganjmadi, Sagod) in the four season (pre-monsoon, post-monsoon, winter and spring periods) throughout the three years (from April, 2011 to March 2014). Six villages from each tehsil were selected for sampling. The samples were collected as composite samples; at every village site, samples were collected from four different points of each village and then mixed together i.e. from thirty villages samples were collected from one hundred twenty points. Samples of groundwater were collected from various sampling sites of five tehsil of Kota district as composite samples for assessment and characterization of their physicochemical properties.

Sampling Methods

To assess the level of groundwater contamination, Sampling of groundwater is done from hand pumps and bore wells located in residential and agricultural areas, as per the standard procedure. Good quality narrow mouth screw-capped polypropylene bottles of two-liter capacity were used to collect the sample. Bottles first washed with dilute nitric acid than thrice with DM water (Demineralised). Before sample collection bottles were rinsed thrice with water to be sampled and then samples were collected.

Sampling Sites

Six villages from each tehsil of Kota district and minimum five locations in a village, so that drawn sample represent the real groundwater quality of the area.

Labeling of the samples

Every sample was coded adequately and mark code on sampling bottles by permanent marker at two places, recorded all the information regarding name of the sampling location, source and date of collection in field book to avoid any confusion and error.

Collection of Samples

Before collection of sample the pipeline of bore wells / hand pumps were flushed for a sufficient period of time, so that actual sample can be collected which represents the actual quality of groundwater. The samples were collected from five spot and then mixed together. Sample bottles were rinsed thrice with the water to be collected and then filled completely to avoid encroachment of air bubble. Sample bottles screw-caped tightly and brought to the laboratory. The samples were preserved in refrigerator at 4^0C. The analysis of pH was made in field with the help of systronic make portable pH meter.

Examination of Samples

Groundwater samples of various locations were analyzed for determination of degree of pollution with respect to the following physicochemical parameters and heavy metals opted for investigation.

(i) pH
(ii) EC (Electrical Conductivity)
(iii) T.D.S. (Total Dissolved Solids)
(iv) T.H. (Total Hardness)
(v) Ca Hardness
(vi) Mg Hardness
(vii) Sodium
(viii) Potassium
(ix) T.A. (Total Alkalinity)
(x) Bicarbonates
(xi) Carbonates
(xii) D. O. (Dissolved Oxygen)
(xiii) B.O.D. (Biological Oxygen Demand)

(xiv) C.O.D. (Chemical Oxygen Demand)

(xv) Chloride

(xvi) Fluoride

(xvii) Nitrate

(xviii) Sulphate

And heavy metals viz.:

(i) Iron

(ii) Cadmium

(iii) Copper

(iv) Zinc

(v) Manganese

(vi) Lead

STANDARD METHODS ADOPTED FOR ANALYSIS

The ground water samples collected from various selected locations were analyzed for physicochemical parameters in order to determine degree of pollution. Standard methods given in "Standard methods for the examination of water and wastewater, 17th edition, 1989, prepared and published jointly by American public health Association (APHA)[9, 11], American water works association (AWWA) and water pollution control federation (WPCF) [191], were used for determination of various physicochemical parameters.

1. pH: Electrometric method no – 4500 B, given on page no – 4 / 95- 101 , was used.
2. CONDUCTIVITY: Laboratory method no – 2510 B, given on page no – 2 / 59 – 61, was used.
3. TOTAL DISSOLVED SOLIDS: Calculation method no – 1030 F, given on page no – 1 / 20 – 21, was used.
4. TOTAL ALKALINITY: The titration method no – 2320 B, given on page no - 2 / 35 - 39, for determination of bicarbonate, carbonate and total alkalinity was followed.
5. TOTAL HARDNESS: for determination of total hardness, titration method no – 2340 C, given on page no – 2 / 53 – 57, was used.

6. CALCIUM HARDNESS: EDTA titration method no – 3500-Ca D, given on page no – 3 / 85 – 87, was used for determination of calcium hardness.
7. MAGNESIUM HARDNESS: Calculation method no 3500-Mg E, given on page no – 3 / 114, was used for calculation of magnesium hardness.
8. SODIUM: Flame Emission Photometric method no – 3500-Na D, given on page no – 3 / 146 – 149, was used for determination of sodium.
9. POTASSIUM: Flame photometric method no – 3500-K D, given on page no – 3 / 125 – 126, was used for estimation of potassium.
10. CHLORIDE: Argentometric method no – 4500-CI- B, given on page no – 4 /68 – 69, was used.
11. SULFATE: Turbidmetric method no – 4500-SO42- E, given on page no – 4 / 207 – 208, was used.
12. NITRATE: Ion-selection nitrate electrode method no – 4500 – NO3- D, given on page no – 4 / 133 -135, was followed.
13. FLUORIDE: Ion-selective electrode method no – 4500 –F- C, given on page no – 4 / 87 – 89, was used for estimation of fluoride.
14. DISSOLVED OXYGEN: Wrinkles method with Azide modification, method no – 4500-O-C, given on page no – 4 / 152 – 156 was followed.
15. CHEMICAL OXYGEN DEMAND (COD): Closed reflux titrametric method no – 5220 C, given on page no – 5 /14 – 15, was used for estimation of chemical oxygen demand.
16. BIOLOGICAL OXYGEN DEMAND (BOD): Method no – 5210 B, given on page no – 5 / 4 – 10 was followed.

The determination of heavy metals concentrations in water sample can be accomplished by various methods i.e. titrametric, gravimetric, colorimrtic, flame photometric method, ion chromatographic, atomic absorption spectrophotometer (AAS) etc. Atomic absorption spectrophotometric method is widely used for

determination of heavy metals present even at very low concentrations in water samples because the technique is relatively simple, versatile, accurate and free from major interferences. Sixty-eight elements can be determined directly from atomic absorption spectrophotometer over a wide range of concentrations from ppm to ppb levels with good precision. The instrument is first calibrated with the standard solutions of metal, to be analyzed, with using corresponding hollow cathode lamp of that metal.

The samples drawn in 500 ml capacity sample bottles were transferred into a clean glass beaker and acidify with concentrated nitric acid. Some more quantity sample was cooled at room temperature, filtered through Millipore filter of 0.45µm pore size and collected into 50 ml glass volumetric flask. Further this was makeup up to mark with DM water. Now the sample is ready for analysis. For analysis of trace heavy metals i.e. Iron, Zinc, Manganese, Copper, Lead, and Chromium by atomic absorption spectrophotometer the standard method no – 3111, given on page no – 3 / 13 – 28 in standard methods for the examination of water and wastewater, 17th edition, 1989, prepared and published joined by American public Health Association water works Association and water pollution Federation[191] were followed.

METHODS FOR COMPUTATION OF SOME IMPORTANT PARAMETERS

AGGRESSIVE INDEX (AI)

AI is derived from the actual pH, total hardness in mg/L as $CaCO_3$ (TA) of the water by the formula

$$AI = pH + \log (TA.TH).$$

Aggressive index values less than 10.0 indicate highly aggressive water; value between 10.0 and 12.0 indicate moderately aggressive water and values greater than 12.0 indicate non-aggressive water[90, 18].

LANGELIER SATURATION INDEX (LSI)

The Langelier Saturation Index (LSI), a measure of a solution's ability to dissolve or deposit calcium carbonate, is often used as an indicator of the corrosivity of water. It is purely an equilibrium index and deals only with the thermodynamic driving force for calcium carbonate scale formation and growth. It simply indicates the driving force for scale formation and growth in terms of pH as a master variable. It provides no indication of how much scale or calcium carbonate will actually precipitate to bring water to equilibrium.

If LSI is negative: No potential to scale, the water will dissolve $CaCO_3$.
If LSI is positive: Scale can form and $CaCO_3$ precipitation may occur.
If LSI is close to Zero: Borderline scale potential.

In order to calculate the LSI, it is necessary to know the total alkalinity (mg/L as $CaCO_3$), the total hardness (mg/L as $CaCO_3$), the total dissolved solids (mg/L TDS), the actual pH, and the temperature of the water (^0C) [218].

LSI is defined as:

$$LSI = pH - pHs \quad \text{——————————} \quad (1)$$

pH is the measured water pH.

pHs is the pH at saturation in calcite or calcium carbonate and is defined as:

$$pHs = (9.3 + A + B) - (C+D) \quad \text{……} \quad (2)$$

Where:-

$$A = (\log_{10} [TDS] - 1)/10 \quad \text{……} \quad (3)$$

$$B = -13.12 \text{ X } \log_{10} (^0C + 273) + 34.55 \quad \text{……} \quad (4)$$

$$C = \text{Log}_{10} [\text{TH as } CaCO_3] - 0.4 \quad \text{……} \quad (5)$$

$$D = \log_{10} [\text{total alkalinity as } CaCO_3] \quad \text{……} \quad (6)$$

From analysed data calculated LSI using equation (1) to (6). The use of the equation developed by Langelier made it possible to predict the of natural or conditioned water to deposit calcium carbonate or to dissolve calcium carbonate.

This is useful in predicting the scaling or corrosive tendencies of the water. If the water dissolves calcium carbonate, the water is corrosive and has a negative value, if the water deposits calcium carbonate; it has a scaling tendency and a positive value.

SODIUM ADSORPTION RATIO (SAR)

The soluble inorganic constituents of irrigation water react with soils as ions rather than as molecules. The principle cations are calcium, magnesium and sodium with small amount of potassium. The principle anions are carbonate, bicarbonate, sulphate and chloride with fluoride and nitrate in low concentration. The alkali hazard involved in the use of water for irrigational purpose is determined by the absolute and relative concentration of cations[140, 138]. If the proportion of sodium is high, the alkali hazard is high and conversely, if calcium and magnesium predominate the hazard is low. The suitability of water for irrigational purpose was studied with the help of criteria given by Richard[157,] Wilcox[217], westcot and Ayers[214]. Following calculations were made to illustrate the irrigational suitability of groundwater.

A ratio of soil extract and irrigation water used to express the relative activity of sodium ions in exchange reaction with soil. It is estimated with the help of the following equation-

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$$

Where Na^{+}, Ca^{2+} and Mg^{2+} ions are expressed in meq/L.

PERCENT SODIUM (% Na)

Sodium percent or the proportion of sodium among all the cations present in water is usually expressed in terms of percent sodium. It is also called as soluble sodium percentage (SSP). It is estimated with following equation-

$$\%Na = \frac{Na^+}{[Ca^{2+}+Mg^{2+}+K^+ +Na^+]} \times 100$$

Where: Ca^{2+}, Mg^{2+}, K^+ and Na^+ ions are expressed in meq/L.

EXCHANGEABLE SODIUM PERCENTAGE (ESP)

It is a degree of saturation of the soil exchange complex with sodium. It is calculated with the help of the following relationship-

$$ESP = \frac{100(-0.0126+0.01475\ SAR)}{1+(-0.0126+0.01475\ SAR)}$$

RESIDUAL SODIUM CARBONATE (RSC)

It is also a index for evaluation of water irrigational purpose and calculated as-

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

Classification of irrigational water given by wilcox[217] is given in Annexure-V; by Richard[157] is shown in Annexure-VI and by westcot and Ayers[214] based on electrical conductance and calculated sodium adsorption ratio are shown in Annexure-VII.

CHAPTER 3

OBSERVATIONS AND RESULTS

OBSERVATIONS AND RESULTS

Water is life, however good quality drinking water is still a dream for most the population. Hence assessing the water quality for human consumption and recreational purpose is of utmost importance. The consumption of high fluoride water causes floristic and skeleton disorder (Annex-III) whereas high nitrate causes methaemoglobinaemia disease[189]. All the quality parameters have equal importance; conversely fluoride and nitrate values are most important due to more hazardous impact on human health. The WHO[215, 216], APHA and Ind. standard for drinking water are given in Annex – II.

It has been roughly assessed that the amount of iron washed due to corrosion is one fourth of the world production. Corrosiveness of water may damage water distribution systems as well as purification systems. In order to determine corrosion potential of ground water of study area, some corrosivity Indices namely Aggressive index (AI) and Langelier saturation index (LSI) are calculated. The corrosion potential corresponding to corrosivity index values is shown in Annex-IV. In maximum part of study area well- developed canal system exists for irrigational purpose but in lean season when canals do not flow, ground water is used for irrigation. Water quality has major impact on soil quality and crop yield. To evaluate irrigational suitability of ground water of study area Exchangeable sodium percentages (ESP) and Residual sodium carbonate (RSC) are calculated. The suitability of water quality for irrigational purpose is shown in Annex-V, VI & VII.

On the basis of quantitative analysis and these calculated indices the ground water quality mapping of the study area framed in following manner:

DIGOD TEHSIL

The quantitative analysis of physicochemical parameters of six village of each tehsil of Kota district for the three years (from April, 2011 to March 2014) during

four seasons (pre-monsoon, post-monsoon winter and spring) in morning and evening time period are shown in Table no - 1 to 6, analysis of heavy metals and of some others physicochemical parameters are presented in Table No – 7 and comparative studies are represented by Fig No – 1A to 1H.

WATER QUALITY PARAMETERS

pH Values

The variations in pH values may be due to increase or decrease of human and other biological activities. The permissible limit of pH values for drinking water is specified as 6.5 to 8.5 as per IS 10500. The pH values of groundwater samples were ranged from 7.6 (GWS/D/12-2011-12/Post-monsoon) to 8.9 (GWS/D/6-2012-13/Pre-monsoon) and (GWS/D/6-2013-14/Pre-monsoon & GWS/D/6-2013-14/Spring) with overall average value 8.30 in successive three years analysis, out of 144 samples only 27 samples have higher value than permissible limit[25].

Conductance

Conductance generally varies according to the season. In pre-monsoon period when water gets concentrated the conductance goes on higher side. Conductance is not too harmful but water with higher conductance is not suitable for drinking, irrigational and other purpose. The values of conductance of groundwater samples are ranged from 502 (GWS/D/7-2011-12/post-monsoon & GWS/D/9-2011-12/post-monsoon) to 1418 µS (GWS/D/6-2012-13/pre-monsoon) with overall average value 985µS of successive three years analysis, lower conductance in post monsoon period is due to dilution from rainwater.

Total Dissolved Solids

Water of high TDS is not suitable for use in boilers and hence restricted industrial use. Normally ground water has a higher total dissolved solids load compared to surface water. The TDS of groundwater samples ranged from 589 (GWS/D/3-2013-14/post-monsoon) to 1734 (GWS/D/7-2012-13/pre-monsoon) mg/L with an average value of 963.5 mg/L. High TDS values observed in pre—monsoon season

as water concentrated due to evaporation. Lower values in post –monsoon was found due dilution of water with rainwater.

Total Alkalinity

Alkalinity of water is its capacity to neutralize a strong acid. According to IS 10500 the maximum allowable concentration of total alkalinity for drinking water is 600 mg/L. Alkalinity in natural waters is due to free hydroxyl ions and hydrolysis of salts formed by weak acids and strong bases such carbonates and bicarbonates. Total alkalinity of groundwater samples varies from 251 (GWS/D/7-2011-12/post-monsoon & GWS/D/9-2011-12/post-monsoon) mg/L to 709 (GWS/D/6-2012-13/Pre-monsoon) mg/L with overall average of 493.2 mg/L of successive three year analysis[26].

Carbonate Alkalinity

In maximum number of analyzed samples carbonates alkalinity ND (Non detectable) and only in 37% samples carbonates alkalinity was detected. The values varied between 3 to 13 mg/L. The minimum value was observed in (GWS/D/1-2013-14/Winter) and maximum in (GWS/D/8-2011-14/Winter).

Bicarbonates Alkalinity

Bicarbonates alkalinity ranged from 251 to 709 mg/L with an overall average of 493.2 mg/L in analyzed samples during successive three years. In sample (GWS/D/7-2011-12/post-monsoon & GWS/D/9-2011-12/post-monsoon) minimum value of bicarbonates alkalinity was observed and in sample (GWS/D/6-2012-13/Pre-monsoon) maximum value of bicarbonates alkalinity was observed.

Total hardness

The major cations imparting hardness are calcium and magnesium. Hardness is the property of water, which prevents the lather formation with soap and increase the boiling point of water. The total hardness of groundwater samples ranged from 219 (GWS/D/3-2012-13/post-monsoon) to 571 (GWS/D/10-2012-13/pre-

monsoon) mg/L with overall average of 415.7 mg/L of successive three years analysis. The anions responsible for hardness are carbonates, bicarbonates, sulphate and chloride. Hardness is temporary if it is associated mainly with carbonates and bicarbonates, and permanents if with sulphate and chloride.

Calcium Hardness

There is no definite trend in values of calcium hardness samples. Calcium is one of the most abundant elements found in natural water. It is important ion in imparting the hardness to the waters. The calcium hardness of groundwater samples ranged from 138 to 366 mg/L with overall average of 253.5 mg/L of successive three years analysis. At high pH much of its quantities may get precipitated as calcium carbonate.

Magnesium Hardness

Magnesium is determined as the difference between the total hardness and calcium hardness. Magnesium also occurs in all kind of natural waters, but its concentration remains generally lower than the calcium hardness. There is no definite trend in values of magnesium hardness in groundwater samples. The magnesium hardness ranged from 69 to 235 mg/L with overall average of 162.1 mg/L of successive three years analysis.

Sodium

Sodium values ranged from 65 to 212 mg/L and the average value of sodium was 141.8 mg/L in all of the studied samples of successive three- years. The maximum value of sodium examined in sample GWS/D/8-2012-13/post-monsoon and the minimum value of sodium measured in sample GWS/D/4-2013-14/post-monsoon.

Potassium

Potassium values ranged from 0.9 to 18.1 mg/L and the average value of potassium was 6.87 mg/L in all of the studied samples of successive three-years. The maximum value of potassium examined in sample GWS/D/12-2012-13/pre-

monsoon. Maximum numbers of samples were having less than 10 mg/L potassium.

Chloride

The most important source of chloride in natural waters is the discharge of sewage. Chloride occurs naturally in all types of waters. In natural fresh waters, its concentration remains quite low. The values observed are within the specified limit of 250 mg/L as per IS 10500. The chloride concentration in groundwater samples varies from 28 to 154 mg/L with overall average of 78.7 mg/l of successive three years analysis.

Sulphate

The maximum allowable limit of sulphates in drinking water as per IS 10500 is 400 mg/L. The higher values of sulphates content may be contributed due to bio chemical, anthropogenic sources and industrial processes etc. Sulphate is a naturally occurring anion found almost in all kinds of water bodies. This is also an important anion imparting hardness to the waters. The sulphate ion produces cathartic effect upon human beings when it is present in excess. The sulphate ion concentration in groundwater samples ranged from 29 to 165 mg/L with overall average of 86.5 mg/L of successive three years analysis.

Nitrate

Domestic sewage, industrial effluents, natural run-off and agricultural wastes are the important sources of it. Nitrate is one of the critical nutrients for the growth of algae and helps accelerating the eutrophication. Nitrate content in groundwater samples varies from 18 to 94 mg/L with overall average of 47.9 mg/L of successive three years analysis. The maximum allowable limit of nitrate in drinking water as per IS 10500 is 45 mg/L. Nitrate ion concentration is very important in drinking water because if it exceeds 45 mg/L it causes blue babies syndrome (Methaemoglobinaemia) in children[7, 27].

Fluoride

Water containing high fluoride concentration is not suitable for drinking water purpose because fluoride causes mottling of teeth, skeletal fluorosis, forward bending of vertebral column, defloration of knee joints[214]. The fluoride ion concentrations in the study were within the specified limit and ranged from 0.4 to 3.2 mg/L with overall average of 1.4 mg/L in successive three years analysis. As per IS 10500 maximum fluoride concentration in drinking water is 1.50 mg/L.

Dissolved Oxygen

The data table reveals that DO values were ranged from 6.1 to 7.2 mg/L for the entire ground water samples and no major variations found in these values. The minimum value of DO was observed in sample GWS/D/2/2011-12 and maximum value in sample GWS/D/3/2013-14.

Biological Oxygen Demand

Values ranged from 0.2 to 0.8 mg/L for the entire ground water samples. BOD was monitored in sample GWS/Lakha-sanija/2013-14 as minimum value and BOD was monitored in samples GWS/Lakha-sanija/2011-12 as maximum values.

Chemical Oxygen Demand

Values were varied from 2.2 to 4.8 mg/L in the entire ground water samples. A maximum value of 4.8 mg/L was monitored in sample GWS/Sarola/2011-12.

Heavy Metals

Heavy metal viz. Fe, Cd, Cu, Zn, Mn, and Pb were analyzed during successive three years. Heavy metals like Cd, Cu, Mn and Zn were Nd (Non detectable) and those samples which have had some values of these metals were under permissible limits of IS 10500 and WHO. Fe values ranged from 0.11 to 0.19 mg/L. These values were within the prescribed limit. Pb was also ND at maximum sites except GWS/ Lakh-sanija, GWS/ Sarola and GWS/ Moondla where values ranged from 0.01 to 0.05 mg/L and these all values were under permissible limits of IS 10500 and WHO recommended standards.

CALCULATED INDICES

Aggressive Index (AI): Calculated values of aggressive index for all the samples analyzed in successive three years was ranged from 13.27 to 14.05 with an overall average of 13.67 Data reveals that maximum samples show non-aggressive nature of corrosivity.

Langelier Saturation Index (LSI)

A calculated value of Langelier saturation index (LSI) was varied from 0.58 to 1.35 with an overall average of 0.97 for all the samples analyzed in successive three years. Use of groundwater without any treatment may result in such manner; 8 samples result in slight scale/encrustation and remaining 10 samples result in mild scale/ encrustation. Data reveals that nature of groundwater samples of study area were neither severe corrosive nor severe scale/encrustation but usually mild conditioning is required.

Percentage Sodium (% Na)

Calculated values of percentage sodium (%Na) were ranged from 41.07 to 42.75 with overall average of 42.59 for all the samples analyzed in pre monsoon seasons in successive three years. The minimum value was found in sample GWS/Sarola during 2011-12. Use of water having excess sodium percentage is not suitable for irrigational purpose. Data reveals that all samples were of good class and suitable for irrigation purpose.

Sodium Adsorption Ratio (SAR)

The calculated values of sodium adsorption ratio (SAR) were ranged from 2.62 to 3.25 with overall average of 2.95 for all the samples analyzed in successive three years. Classification of groundwater samples as per US agricultural norms reveals that all samples were of low (S_1) class.

Residual Sodium Carbonate (RSC)

The calculated values of residual sodium carbonates (RSC) were ranged from -1.2 to 3.01 with overall average of 2.35 for all the samples analyzed in successive three years. Maximum value of RSC was calculated in sample GWS/Moondla-2012-13 and minimum value was in sample GWS/Bhandahera-2011-12.

Exchangeable Sodium Percentage (ESP)

The calculated values of exchangeable sodium percentage (ESP) were ranged from 2.54 to 3.41 with overall average of 3.0 for all the samples analyzed in successive three years. Maximum value of ESP was calculated in sample GWS/Bhandahera-2012-13 and minimum value was in sample GWS/Notara-2013-14.

Table: 1

Physico-Chemical Parameters of Groundwater of Digod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Lakh-sanija (GWS) D1-Morning D2-Evening	2011-12	Pre Monsoon	Morning	8.3	1228	983	614	ND	614	480	281	199	145	9.2	60	75	34	1.9
			Evening	8.5	1244	982	622	ND	622	489	290	198	155	14.2	67	87	41	2.4
		Post Monsoon	Morning	8.2	820	774	410	ND	410	256	150	105	116	3.2	31	40	21	0.8
			Evening	8.2	994	774	518	ND	497	343	215	129	119	5.4	30	51	20	1.2
		Winter	Morning	8.3	990	840	495	ND	495	312	179	132	148	6.2	44	56	30	1.1
			Evening	8.3	1124	840	562	ND	562	431	256	175	137	8.8	55	70	30	1.8
		Spring	Morning	8.2	1026	908	513	ND	513	376	220	156	141	8.5	56	70	32	1.8
			Evening	8.4	1236	907	618	ND	618	470	286	184	154	13.7	62	80	38	2.1
	2012-13	Pre Monsoon	Morning	8.5	1242	1003	621	ND	621	493	293	200	150	9.7	67	80	38	1.8
			Evening	8.7	1262	1002	631	ND	631	497	295	201	158	14.8	69	89	42	2.6
		Post Monsoon	Morning	8.2	802	796	401	ND	401	254	152	101	115	1.9	38	34	21	0.7
			Evening	8.2	902	796	451	ND	451	331	205	127	113	3.5	35	51	31	1.7
		Winter	Morning	8.3	1004	860	502	ND	502	351	201	151	130	4.2	41	52	30	1.2
			Evening	8.4	1202	859	601	ND	601	457	281	176	146	5.7	59	61	38	2.2
		Spring	Morning	8.4	1192	925	596	ND	596	433	245	188	149	7.5	53	61	36	1.6
			Evening	8.5	1256	924	628	ND	628	476	290	185	163	8.4	67	79	41	2.4
	2013-14	Pre Monsoon	Morning	8.4	1234	960	617	ND	617	480	281	198	149	8.7	65	73	33	2.1
			Evening	8.7	1252	961	640	ND	626	497	291	206	156	13.4	68	88	44	2.3
		Post Monsoon	Morning	8.2	820	752	410	ND	410	306	190	116	105	2.3	40	49	20	1.3
			Evening	8.3	912	754	456	ND	456	331	196	135	124	4.2	49	50	34	1.8
		Winter	Morning	8.3	992	814	499	3	496	396	236	160	126	5.6	59	69	29	1.5
			Evening	8.5	1064	817	532	ND	532	392	235	157	147	6.4	56	71	38	2.1
		Spring	Morning	8.5	1152	881	576	ND	576	458	280	177	139	7.8	63	71	35	2.2
			Evening	8.6	1206	886	603	ND	603	473	278	195	152	9.7	65	78	43	2.7

Note: All Values Except pH & EC are in mg/L.

Table: 2

Physico-Chemical Parameters of Groundwater of Digod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Takarwara (GWS) D3-Morning D4-Evening	2011-12	Pre Monsoon	Morning	8.5	962	816	481	ND	481	355	214	141	121	6.7	48	49	30	1.4
			Evening	8.2	990	838	495	ND	495	370	221	149	139	7.8	58	73	34	1.5
		Post Monsoon	Morning	8.2	614	611	307	ND	307	230	150	80	74	2.8	30	29	19	0.8
			Evening	7.9	634	635	327	10	317	228	138	90	86	1.1	30	39	18	0.9
		Winter	Morning	8.3	702	680	351	ND	351	272	161	110	89	3.7	38	40	28	1.1
			Evening	8.0	796	702	398	ND	398	281	175	106	117	4.6	40	59	29	1.3
		Spring	Morning	8.3	958	742	479	ND	479	350	211	139	116	5.8	41	45	30	1.5
			Evening	8.1	956	763	478	ND	478	356	215	141	130	6.8	50	69	32	1.8
	2012-13	Pre Monsoon	Morning	8.6	990	840	495	ND	495	371	225	145	126	7.1	51	53	37	1.5
			Evening	8.4	1038	863	519	ND	519	390	234	156	143	8.4	59	75	38	1.6
		Post Monsoon	Morning	8.2	596	631	298	ND	298	219	150	69	80	3.2	32	36	18	0.9
			Evening	7.9	664	655	332	ND	332	235	140	95	95	1.6	35	37	29	1.1
		Winter	Morning	8.3	762	695	381	ND	381	276	165	111	102	4.9	39	46	26	1.1
			Evening	8.0	864	718	432	ND	432	287	157	130	124	3.8	42	43	31	1.5
		Spring	Morning	8.5	964	759	482	ND	482	360	222	139	121	6.3	48	51	32	1.4
			Evening	8.2	1002	781	501	ND	501	366	220	146	138	7.8	52	68	37	1.4
	2013-14	Pre Monsoon	Morning	8.6	974	795	487	ND	487	367	226	141	124	6.4	51	54	36	1.6
			Evening	8.3	1024	817	512	ND	512	387	232	154	141	8.8	59	74	37	1.4
		Post Monsoon	Morning	8.2	602	589	301	ND	301	238	163	75	70	1.3	28	31	23	1.1
			Evening	7.9	532	613	271	5	266	227	142	85	65	1.1	31	38	26	0.9
		Winter	Morning	8.4	850	655	425	ND	425	321	201	120	106	3.3	40	46	30	1.4
			Evening	8.2	884	679	442	ND	442	341	215	125	114	3.2	45	58	32	1.2
		Spring	Morning	8.5	962	718	481	ND	481	358	221	137	123	5.2	50	52	33	1.5
			Evening	8.3	1024	742	512	ND	512	375	229	146	138	6.8	54	64	36	1.3

Note: All Values Except pH & EC are in mg/L.

Table: 3

Physico-Chemical Parameters of Groundwater of Digod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Notara (GWS) D5-Morning D6-Evening	2011-12	Pre Monsoon	Morning	8.8	1358	950	685	6	679	524	298	226	169	4.4	68	84	39	2.2
			Evening	8.5	1366	950	683	ND	683	502	293	208	172	4.8	62	77	34	2.3
		Post Monsoon	Morning	8.5	858	745	429	ND	429	307	186	121	109	0.9	35	45	21	2.1
			Evening	8.2	786	744	393	ND	393	294	188	106	92	1.2	32	39	20	1.1
		Winter	Morning	8.6	1032	808	516	ND	516	391	227	164	136	2.8	52	68	34	2.4
			Evening	8.3	990	808	495	ND	495	362	216	145	126	3.2	42	59	28	1.9
		Spring	Morning	8.7	1248	867	624	ND	624	468	256	212	159	3.6	61	72	37	2.5
			Evening	8.5	1220	866	610	ND	610	453	274	179	148	4.1	52	65	31	2.2
	2012-13	Pre Monsoon	Morning	8.9	1362	972	681	ND	681	533	298	235	177	5.4	74	94	47	2.7
			Evening	8.6	1418	971	709	ND	709	532	315	216	178	6.3	68	79	42	2.5
		Post Monsoon	Morning	8.5	890	768	445	ND	445	334	207	127	116	1.9	46	48	32	2.0
			Evening	8.2	830	766	415	ND	415	302	185	117	101	2.2	37	33	26	2.1
		Winter	Morning	8.7	1064	836	532	ND	532	383	231	151	141	4.3	53	54	35	2.4
			Evening	8.4	1108	832	554	ND	554	385	216	169	137	4.5	43	44	30	2.6
		Spring	Morning	8.8	1250	892	625	ND	625	470	260	210	168	5.2	63	84	45	2.7
			Evening	8.5	1270	888	635	ND	635	455	269	186	167	5.8	58	68	39	3.2
	2013-14	Pre Monsoon	Morning	8.9	1362	928	681	ND	681	527	298	228	168	4.8	68	82	39	2.6
			Evening	8.7	1396	927	698	ND	698	520	307	212	175	5.1	66	78	40	2.1
		Post Monsoon	Morning	8.6	914	720	465	8	457	327	201	126	114	1.8	35	42	29	2.1
			Evening	8.3	906	720	453	ND	453	330	201	129	116	2.2	42	49	25	1.2
		Winter	Morning	8.8	1068	782	534	ND	534	409	244	165	145	3.6	59	76	36	2.4
			Evening	8.5	1142	783	571	ND	571	411	245	166	147	4.6	49	66	32	1.7
		Spring	Morning	8.9	1266	842	633	ND	633	489	285	204	159	4.2	65	79	35	2.5
			Evening	8.6	1316	842	658	ND	658	477	279	198	168	6.4	60	72	38	1.9

Note: All Values Except pH & EC are in mg/L.

Table: 4

Physico-Chemical Parameters of Groundwater of Digod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Sarola (GWS) D7-Morning D8-Evening	2011-12	Pre Monsoon	Morning	8.5	1046	1711	523	ND	523	504	294	210	198	5.6	138	150	86	1.2
			Evening	8.6	1062	1705	531	ND	531	523	303	221	202	5.9	143	159	89	1.5
		Post Monsoon	Morning	8.2	502	1502	251	ND	251	297	198	99	88	2.1	81	90	42	0.7
			Evening	8.2	596	1497	298	ND	298	303	179	124	108	2.1	85	91	34	0.8
		Winter	Morning	8.3	602	1574	301	ND	301	374	228	146	135	3.5	120	134	78	0.9
			Evening	8.3	840	1570	433	13	420	471	287	185	150	3.7	125	146	69	1.1
		Spring	Morning	8.4	982	1633	491	ND	491	484	290	194	182	4.3	131	140	80	1.1
			Evening	8.5	1038	1628	519	ND	519	511	299	212	195	4.2	138	155	82	1.3
	2012-13	Pre Monsoon	Morning	8.7	1076	1734	538	ND	538	533	307	226	206	6.1	149	162	90	1.4
			Evening	8.8	1064	1729	532	ND	532	520	286	235	212	6.5	152	161	94	1.6
		Post Monsoon	Morning	8.3	618	1528	309	ND	309	364	231	133	119	2.9	110	115	52	0.8
			Evening	8.3	620	1524	310	ND	310	335	199	137	116	2.8	99	101	46	0.6
		Winter	Morning	8.5	840	1598	420	ND	420	450	274	176	164	5.9	135	149	63	1.1
			Evening	8.5	896	1595	448	ND	448	422	226	196	186	5.3	125	146	76	0.7
		Spring	Morning	8.6	1026	1655	521	8	513	514	299	215	196	6.4	142	159	87	1.5
			Evening	8.7	1034	1652	517	ND	517	505	276	230	199	6.2	146	151	83	1.2
	2013-14	Pre Monsoon	Morning	8.6	1072	1686	536	ND	536	527	306	221	204	5.9	145	159	90	1.5
			Evening	8.8	1076	1680	538	ND	538	526	304	221	205	5.1	154	165	64	1.2
		Post Monsoon	Morning	8.3	602	1479	301	ND	301	357	225	131	99	2.9	96	99	46	1.1
			Evening	8.3	604	1474	302	ND	302	326	192	135	115	2.8	103	109	26	0.7
		Winter	Morning	8.4	840	1552	420	ND	420	454	269	185	162	5.8	135	146	66	1.3
			Evening	8.5	852	1549	426	ND	426	444	246	198	172	5.1	145	151	47	1.1
		Spring	Morning	8.6	1006	1611	503	ND	503	499	286	212	189	6.8	140	151	75	1.4
			Evening	8.7	1006	1606	503	ND	503	488	278	210	197	6.7	150	158	59	1.3

Note: All Values Except pH & EC are in mg/L.

Table: 5

Physico-Chemical Parameters of Groundwater of Digod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Moondla (GWS) D9-Morning D10-Evening	2011-12	Pre Monsoon	Morning	8.1	984	899	492	ND	492	538	348	190	162	7.4	138	145	78	1.4
			Evening	8.1	1016	903	508	ND	508	548	350	197	170	7.9	140	155	79	1.2
		Post Monsoon	Morning	7.7	502	683	251	ND	251	295	217	78	67	4.3	65	75	32	0.5
			Evening	7.8	664	688	332	ND	332	391	265	125	105	4.2	101	110	45	0.4
		Winter	Morning	7.9	674	758	337	ND	337	383	297	86	126	5.9	127	95	62	0.9
			Evening	7.9	840	764	420	ND	420	466	298	168	149	6.2	129	138	66	0.8
		Spring	Morning	8.0	924	810	462	ND	462	496	320	175	157	6.7	135	132	69	1.2
			Evening	8.0	960	818	480	ND	480	503	317	186	166	6.8	132	145	69	1.1
	2012-13	Pre Monsoon	Morning	8.3	1022	925	511	ND	511	558	358	200	169	9.4	142	153	82	1.6
			Evening	8.3	1068	928	534	ND	534	571	366	205	180	8.9	144	164	84	1.1
		Post Monsoon	Morning	7.9	620	711	310	ND	310	337	235	101	97	5.2	75	86	62	0.8
			Evening	7.8	634	714	317	ND	317	390	255	135	116	4.8	116	120	55	0.7
		Winter	Morning	8.1	790	785	395	ND	395	458	311	147	140	7.3	129	130	75	1.1
			Evening	8.1	818	788	409	ND	409	470	303	167	136	7.1	126	128	69	0.9
		Spring	Morning	8.3	930	838	465	ND	465	526	341	186	157	8.5	139	146	81	1.4
			Evening	8.2	1042	842	521	ND	521	544	346	198	170	8.3	136	142	78	1.2
	2013-14	Pre Monsoon	Morning	8.4	1012	877	506	ND	506	545	351	194	166	8.4	138	143	82	1.5
			Evening	8.3	1024	881	512	ND	512	563	361	202	172	8.1	142	162	87	0.8
		Post Monsoon	Morning	8.0	546	663	273	ND	273	330	235	95	74	4.3	75	85	36	1.1
			Evening	7.9	736	668	368	ND	368	427	290	138	114	3.8	105	110	65	0.5
		Winter	Morning	8.2	826	738	413	ND	413	454	286	169	146	6.8	123	127	75	1.2
			Evening	8.1	840	744	420	ND	420	495	335	159	145	6.2	131	150	74	0.7
		Spring	Morning	8.3	996	791	498	ND	498	534	346	189	158	8.3	133	140	74	1.4
			Evening	8.2	1016	798	508	ND	508	555	359	197	166	7.6	138	154	81	0.9

Note: All Values Except pH & EC are in mg/L.

Table: 6

Physico-Chemical Parameters of Groundwater of Digod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Bhandahera (GWS) D11-Morning D12-Evening	2011-12	Pre Monsoon	Morning	8.0	1202	1053	601	ND	601	481	291	190	160	13.1	80	78	62	0.8
			Evening	8.0	1224	1056	612	ND	612	495	296	198	162	15.3	84	81	64	1.1
		Post Monsoon	Morning	7.7	748	836	385	11	374	299	194	105	93	6.5	46	41	35	0.4
			Evening	7.6	900	838	450	ND	450	333	212	122	112	12.7	49	44	39	0.4
		Winter	Morning	7.8	942	914	471	ND	471	361	231	130	126	8.5	59	53	46	0.6
			Evening	7.8	1054	916	527	ND	527	395	248	147	138	13.5	58	55	59	0.5
		Spring	Morning	8.0	1064	962	532	ND	532	421	268	153	146	11.4	74	68	58	0.7
			Evening	8.1	1196	964	598	ND	598	472	288	184	155	14.8	76	71	60	0.9
	2012-13	Pre Monsoon	Morning	8.2	1248	1081	624	ND	624	498	299	199	176	15.2	95	83	70	0.9
			Evening	8.2	1288	1085	644	ND	644	516	310	206	182	18.1	97	90	72	1.7
		Post Monsoon	Morning	7.8	978	865	489	ND	489	351	220	130	125	12.3	55	42	35	0.6
			Evening	7.8	970	868	485	ND	485	345	215	130	118	13.9	46	41	35	0.7
		Winter	Morning	8.0	1096	942	548	ND	548	411	246	165	150	13.2	71	62	52	0.8
			Evening	8.0	1156	944	578	ND	578	433	276	157	165	16.3	59	107	51	1.2
		Spring	Morning	8.2	1226	991	613	ND	613	474	287	187	169	14.2	81	78	61	1.1
			Evening	8.2	1268	994	634	ND	634	490	293	198	174	17.6	86	81	64	1.4
	2013-14	Pre Monsoon	Morning	8.2	1222	1034	611	ND	611	489	293	196	160	14.1	81	77	63	0.7
			Evening	8.2	1276	1039	638	ND	638	495	301	193	174	16.3	80	86	66	1.3
		Post Monsoon	Morning	7.8	912	819	456	ND	456	321	205	115	105	9.2	37	30	29	0.4
			Evening	7.8	902	823	451	ND	451	347	222	125	106	11.2	45	49	32	0.8
		Winter	Morning	8.0	1098	896	549	ND	549	418	261	156	146	11.2	65	62	55	0.5
			Evening	8.1	1150	900	582	7	575	431	265	165	152	12.5	65	70	47	1.1
		Spring	Morning	8.2	1196	946	598	ND	598	477	288	189	155	13.4	80	70	62	0.8
			Evening	8.3	1224	951	612	ND	612	479	295	184	164	13.4	76	80	62	1.4

Note: All Values Except pH & EC are in mg/L.

Table: 7

Heavy Metals Concentration and Some Physicochemical Analysis of Digod Tehsil

S. No.	Name of Location	Year	Parameters			Trace Heavy Metal						Data Interpretation					
			DO	BOD	COD	Fe	Cd	Cu	Zn	Mn	Pb	AI	LSI	%Na	SAR	RSC	ESP
1	Lakh-Sanija (GWS)	2011-12	6.2	0.7	2.7	0.11	ND	0.11	0.11	0.22	0.01	13.61	0.90	43.27	3.08	2.94	3.18
		2012-13	6.5	0.6	4.5	0.12	ND	0.16	0.13	0.21	0.02	13.73	1.02	42.54	3.03	2.85	3.11
		2013-14	6.7	0.4	3.2	0.14	ND	0.12	0.12	0.19	0.01	13.77	1.07	41.34	2.92	2.46	2.96
2	Takarwara (GWS)	2011-12	6.1	0.8	4.1	0.16	ND	ND	ND	ND	ND	13.56	0.87	41.07	2.72	2.44	2.67
		2012-13	6.8	0.3	2.5	0.17	ND	ND	ND	ND	ND	13.66	0.97	42.07	2.83	2.45	2.83
		2013-14	6.9	0.2	3.5	0.13	ND	ND	ND	ND	ND	13.72	1.03	41.68	2.81	2.33	2.80
3	Notara (GWS)	2011-12	6.3	0.5	3.6	0.14	ND	0.12	0.18	0.22	ND	13.27	0.58	43.11	2.70	2.16	2.64
		2012-13	6.7	0.3	2.8	0.19	ND	0.17	0.21	0.23	ND	13.36	0.67	44.28	2.85	2.34	2.86
		2013-14	7.2	0.2	4.7	0.13	ND	0.21	0.14	0.24	ND	13.42	0.74	41.51	2.62	2.03	2.54
4	Sarola (GWS)	2011-12	6.2	0.6	4.8	0.12	ND	ND	ND	ND	0.01	13.57	0.87	43.67	2.97	2.53	3.02
		2012-13	6.8	0.2	2.2	0.14	ND	ND	ND	ND	0.05	13.67	0.96	44.33	3.10	2.67	3.20
		2013-14	6.3	0.3	2.3	0.15	ND	ND	ND	ND	0.04	13.73	1.04	41.97	2.87	2.39	2.89
5	Moondla (GWS)	2011-12	6.5	0.2	3.1	0.13	ND	ND	0.14	0.31	0.03	13.83	1.12	42.06	2.96	2.82	3.01
		2012-13	6.4	0.3	3.5	0.15	ND	ND	0.13	0.29	0.05	13.94	1.22	42.86	3.12	3.01	3.23
		2013-14	6.2	0.7	3.6	0.12	ND	ND	0.11	0.27	0.02	14.05	1.35	42.44	3.10	2.99	3.20
6	Bhandahera (GWS)	2011-12	6.3	0.6	2.5	0.12	ND	0.27	ND	0.21	ND	13.61	0.90	42.52	3.04	1.20	3.11
		2012-13	6.8	0.3	2.8	0.11	ND	0.21	ND	0.19	ND	13.79	1.07	43.27	3.25	1.40	3.41
		2013-14	7.1	0.2	3.8	0.12	ND	0.22	ND	0.17	ND	13.84	1.12	42.75	3.22	1.41	3.36

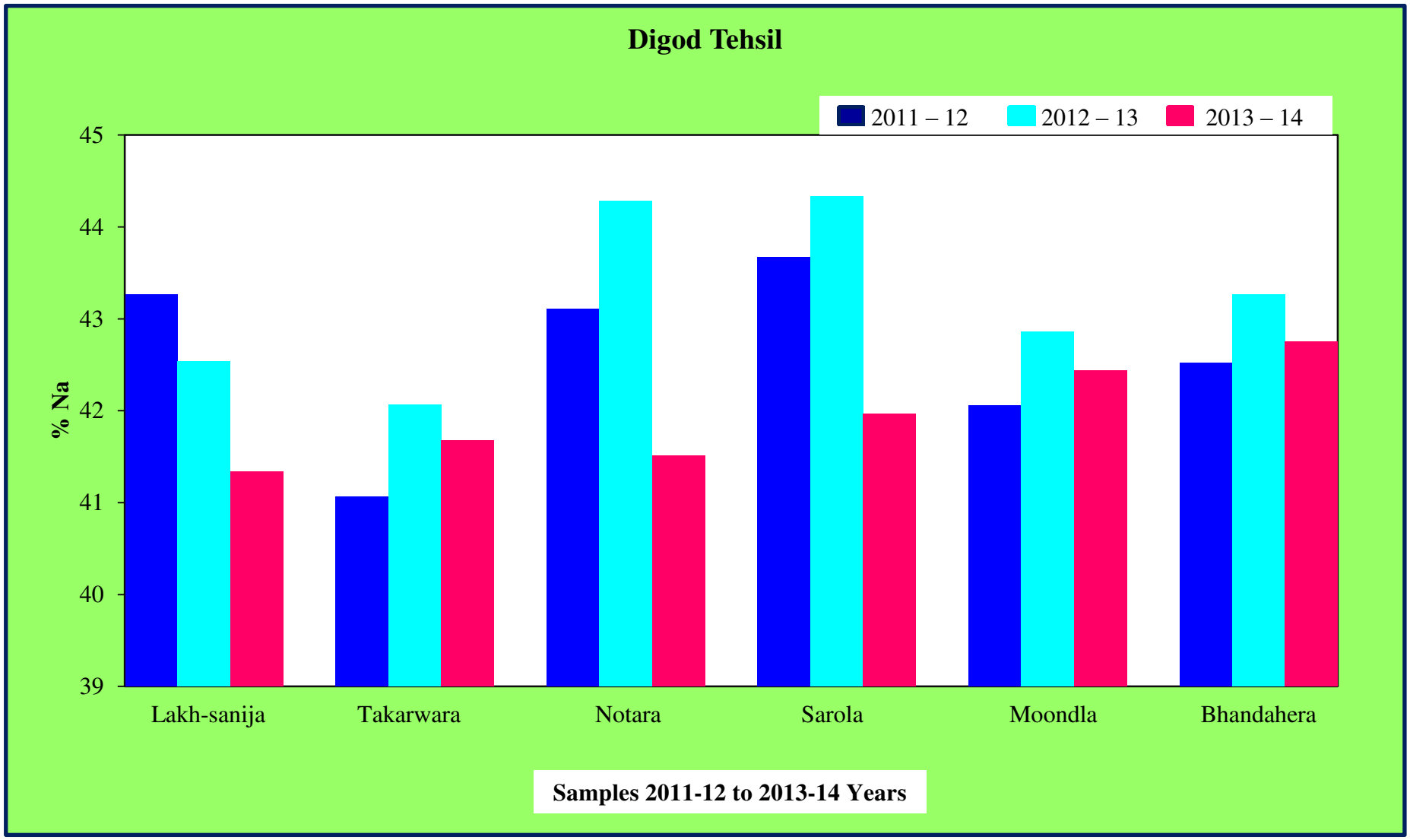

Fig 1A: Comparative Study of % Na in Digod Tehsil for Three Years

Fig 1B: Comparative Study of AI in Digod Tehsil for Three Years

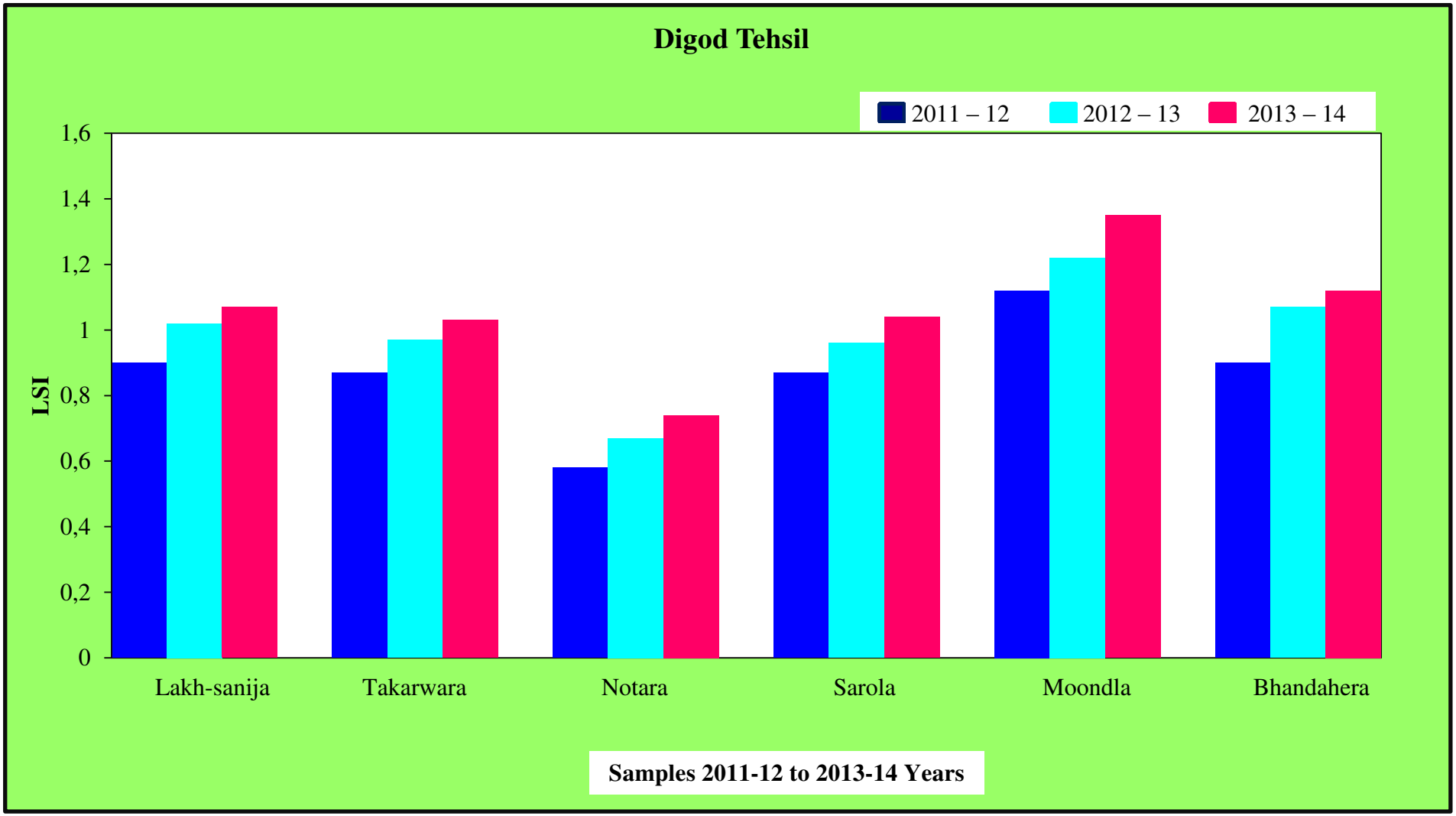

Fig 1C: Comparative Study of LSI in Digod Tehsil for Three Years

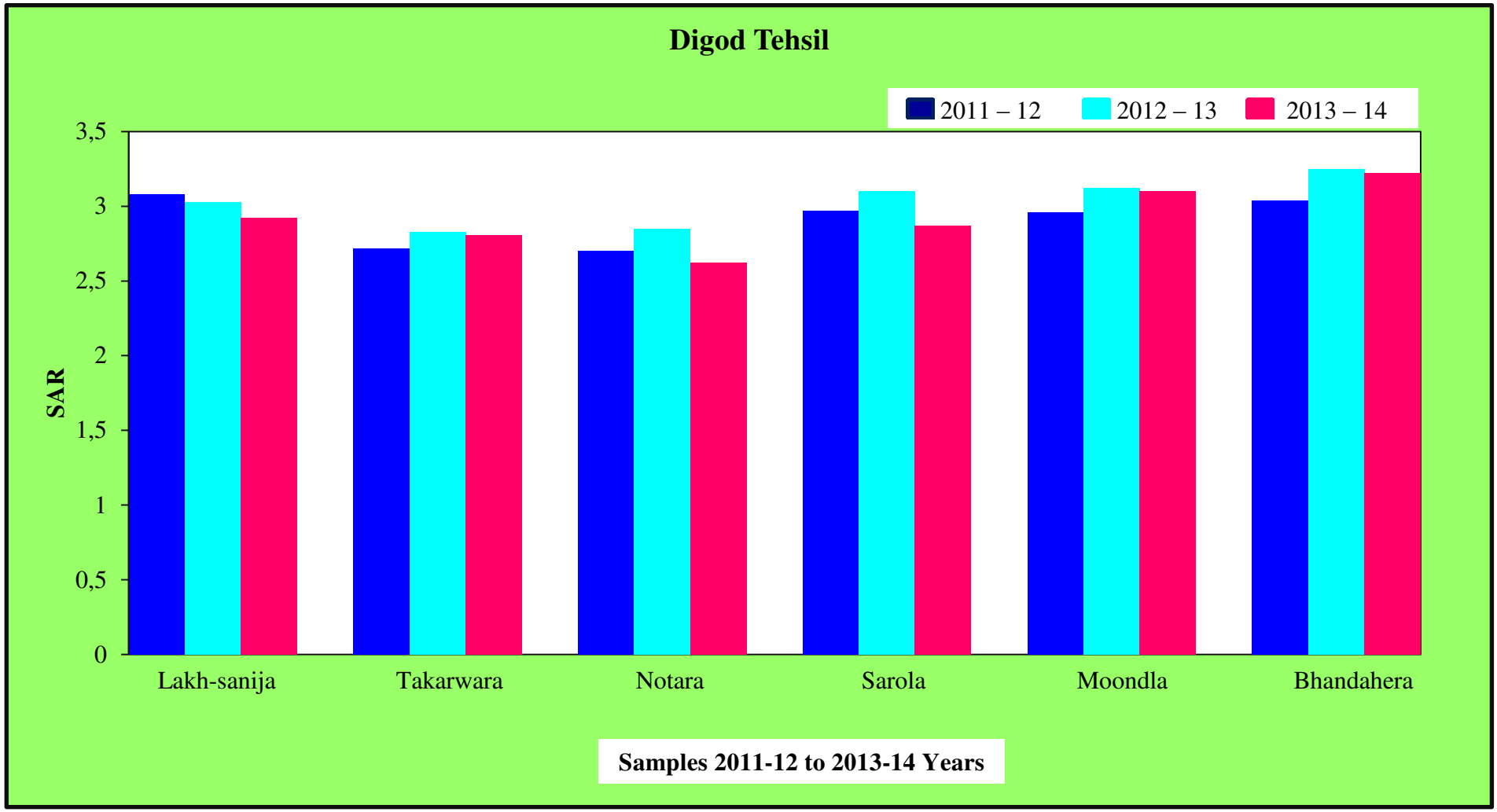

Fig 1D: Comparative Study of SAR in Digod Tehsil for Three Years

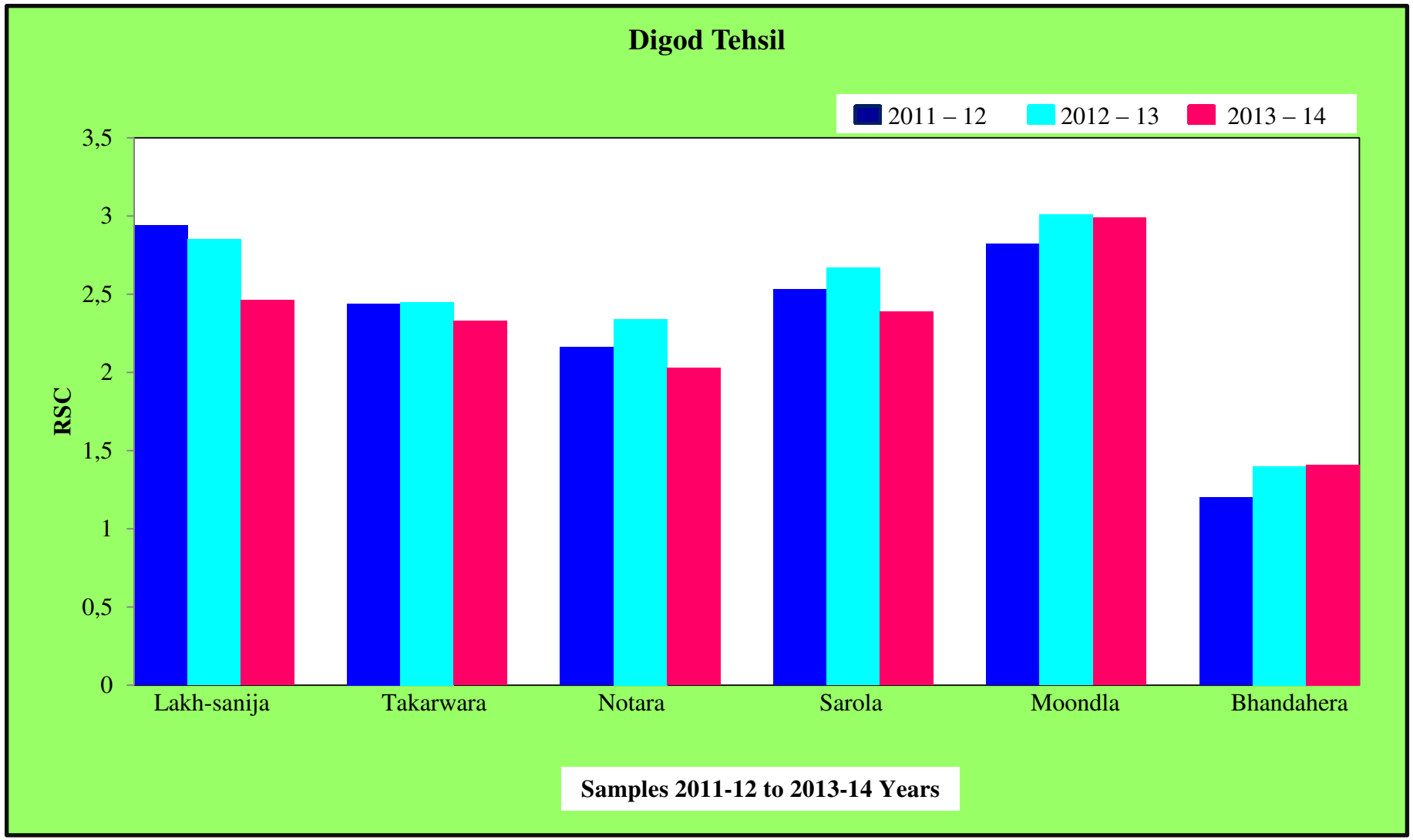

Fig 1E: Comparative Study of RSC in Digod Tehsil for Three Years

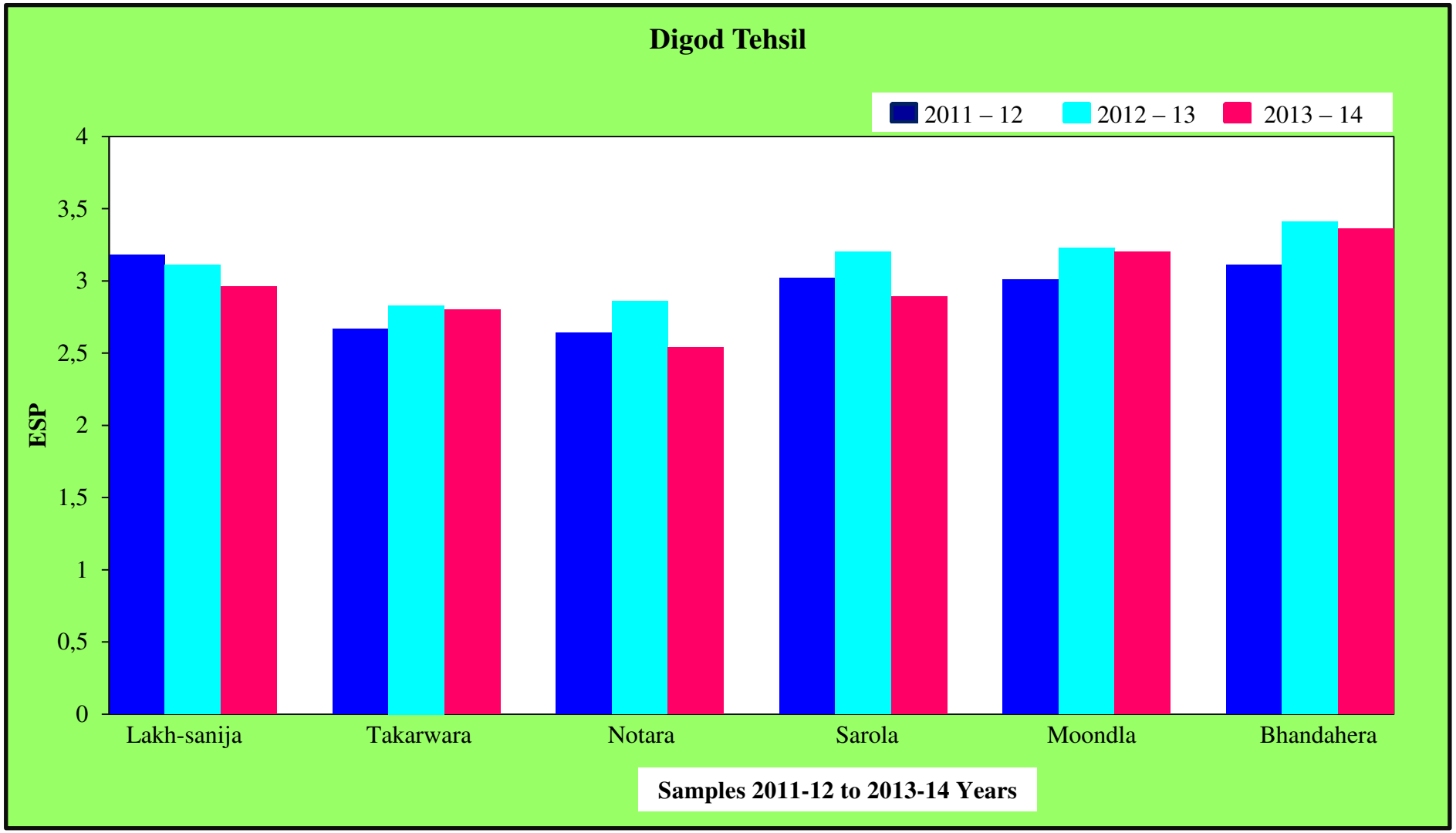

Fig 1F: Comparative Study of ESP in Digod Tehsil for Three Years

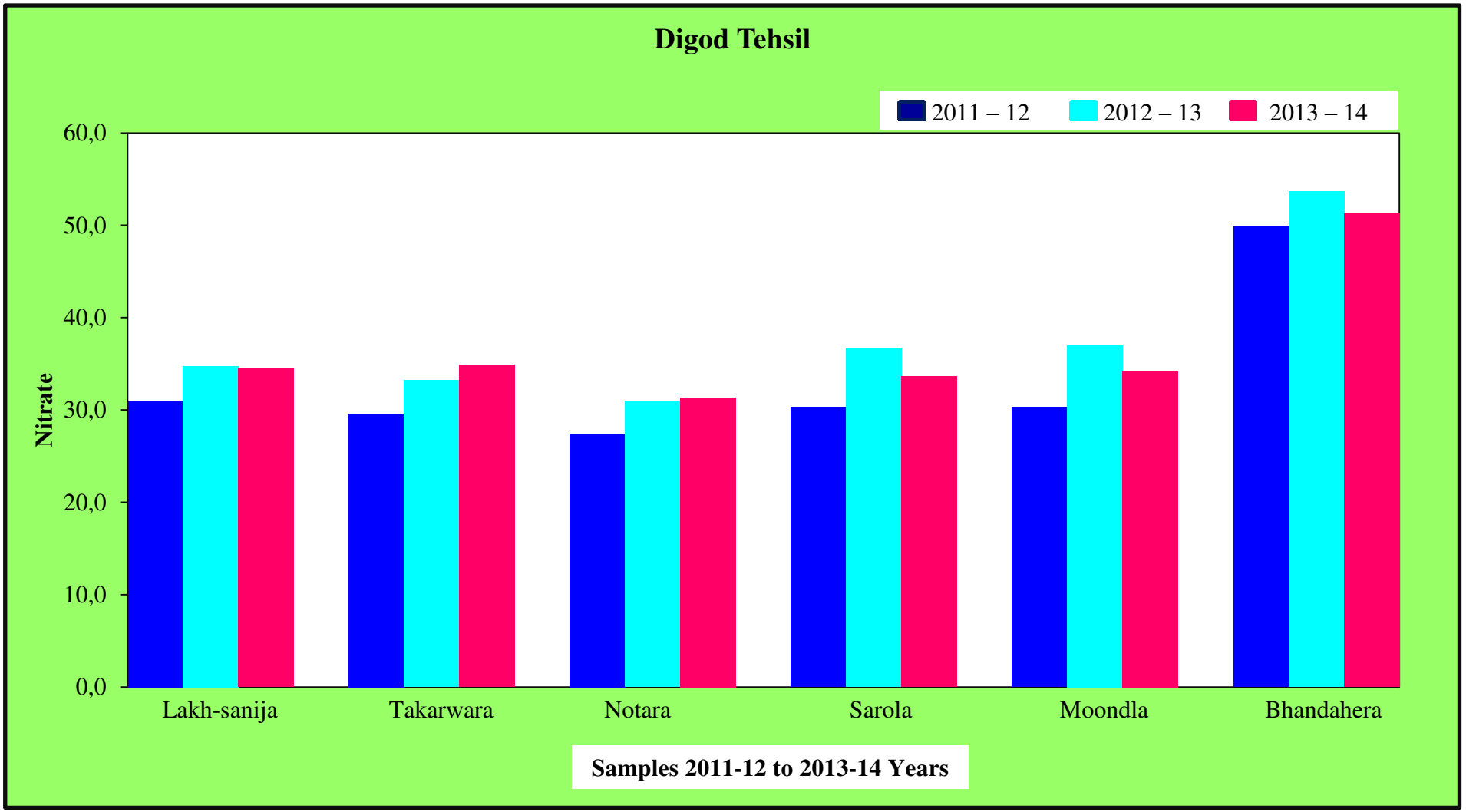

Fig 1G: Comparative Study of Nitrate in Digod Tehsil for Three Years

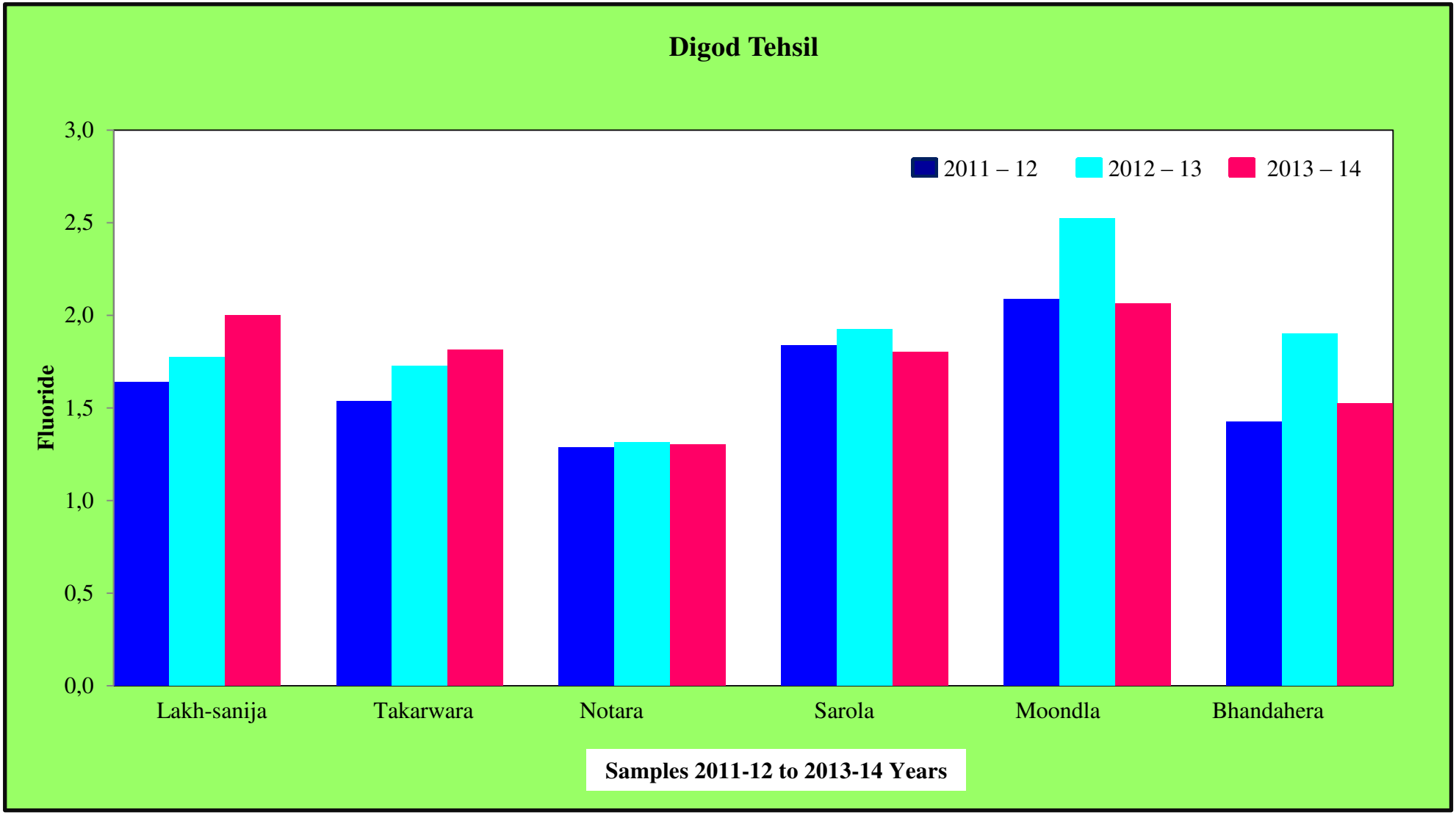

Fig 1H: Comparative Study of Fluoride in Digod Tehsil for Three Years

ITAWA TEHSIL

The quantitative analysis of physicochemical parameters of six village of each tehsil of Kota district for the three years (from April, 2011 to March 2014) during four seasons (pre-monsoon, post-monsoon winter and spring) in morning and evening time period are shown in Table no - 8 to 13, analysis of heavy metals and of some others physicochemical parameters are presented in Table No – 14 and comparative studies are represented by Fig No – 2A to 2H.

WATER QUALITY PARAMETERS

pH Values

The pH values of groundwater samples were ranged from 5.6 (GWS/I/7-2011-12/post-monsoon) to 9.3 (GWS/I/1-2013-14/pre-monsoon) with overall average value 7.76 in successive three years analysis, out of 144 samples only 02 samples have higher value than permissible limit. The permissible limit of pH values for drinking water is specified as 6.5 to 8.5 as per IS 10500.

Conductance

The values of conductance of groundwater samples are ranged from 608 (GWS/I/11-2012-13/post-monsoon) to 1755 µS (GWS/I/3-2012-13/Spring) with overall average value 1159.7µS of successive three years analysis, lower conductance in post monsoon period is due to dilution from rainwater.

Total Dissolved Solids

The TDS of groundwater samples ranged from 443 (GWS/I/4-2013-14/post-monsoon) to 1330 (GWS/I/7-2012-13/pre-monsoon) mg/L with an average value of 780.5 mg/L. High TDS values observed in pre-monsoon season as water concentrated due to evaporation. Lower values in post-monsoon was found due to dilution of water with rainwater.

Total Alkalinity

Alkalinity in natural waters is due to free hydroxyl ions and hydrolysis of salts formed by weak acids and strong bases such carbonates and bicarbonates. Total alkalinity of groundwater samples varies from 59 (GWS/I/11-2011-12/post-monsoon mg/L) to 557 (GWS/I/8-2013-14/Pre-monsoon mg/L) with overall average of 328.7 mg/L of successive three years analysis. According to IS 10500 the maximum allowable concentration of total alkalinity for drinking water is 600 mg/L. Alkalinity of water is its capacity to neutralize a strong acid.

Carbonate Alkalinity

In maximum number of analyzed samples carbonates alkalinity ND (Non detectable) and only in 10% samples carbonates alkalinity was detected. The values varied between 2 to 24 mg/L. The minimum value was observed in GWS/I/5-2011-12/post-monsoon and maximum in GWS/I/7-2012-13/post-monsoon.

Bicarbonates Alkalinity

Bicarbonates alkalinity ranged from 54 to 557 mg/L with an overall average of 327.8 mg/L in analyzed samples during successive three years. In sample GWS/I/11-2012-13/post- monsoon minimum value of bicarbonates alkalinity was observed and maximum value of bicarbonates alkalinity was observed and in sample GWS/I/8-2013-14/pre-monsoon was surveyed.

Total hardness

The total hardness of groundwater samples ranged from 32 (GWS/I/10-2012-13/post-monsoon) to 533 (GWS/I/11-2013-14/pre-monsoon mg/L) with overall average of 232.6 mg/L of successive three years analysis.

Calcium Hardness

The calcium hardness of groundwater samples ranged from 28 to 297 mg/L with overall average of 140.1 mg/L of successive three years analysis. There is no definite trend in values of calcium hardness samples.

Magnesium Hardness

Magnesium is determined as the difference between the total hardness and calcium hardness. There is no definite trend in values of magnesium hardness in groundwater samples. The magnesium hardness ranged from 14 to 237 mg/L with overall average of 92.5 mg/L of successive three years analysis.

Sodium

Sodium values ranged from 67 to 215 mg/L and the average values of sodium was 152.4 mg/L in all of the studied samples of successive three- years. The maximum value of sodium examined in sample GWS/I/10-2012-13/post-monsoon and the minimum value of sodium measured in sample GWS/I/7-2013-14/pre-monsoon.

Potassium

Potassium values ranged from 0.9 to 19.3 mg/L and the average value of potassium was 8.3 mg/L in all of the studied samples of successive three years. The maximum value of potassium examined in sample GWS/I/8-2013-14/pre-monsoon.

Chloride

In natural fresh waters, chloride concentration remains quite low. The most important source of chloride in natural waters is the discharge of sewage. The values observed are within the specified limit of 250 mg/L as per IS 10500. The chloride concentration in groundwater samples varies from 17 to 237 mg/L with overall average of 83.1 mg/l of successive three years analysis.

Sulphate

The sulphate ion concentration in groundwater samples ranged from 21 to 279 mg/L with overall average of 100.2 mg/L of successive three years analysis. The maximum allowable limit of sulphates in drinking water as per IS 10500 is 400 mg/L.

Nitrate

The maximum allowable limit of nitrate in drinking water as per IS 10500 is 45 mg/L. Nitrate content in groundwater samples varies from 12 to 69 mg/L with overall average of 30.8 mg/L of successive three years analysis.

Fluoride

The fluoride ion concentrations in the study were within the specified limit and ranged from 0.3 to 1.9 mg/L with overall average of 1.24 mg/L in successive three years analysis. As per IS 10500 maximum fluoride concentration in drinking water is 1.50mg/L.

Dissolved Oxygen

The data table reveals that DO values were ranged from 5.1 to 6.8 mg/L for the entire ground water samples during pre-monsoon season and no major variations found in these values. The minimum value of DO was observed in sample GWS/I/7-8/2012-13 and maximum value in sample GWS/I/3-4/2013-14 and GWS/I/11-12/2012-13.

Biological Oxygen Demand

Values ranged from 1.4 to 3.8 mg/L for the entire ground water samples during pre-monsoon seasons. BOD was monitored in sample GWS/Rajopa/2011-12 as minimum value and BOD was monitored in samples GWS/Ayana/2013-14 as maximum values.

Chemical Oxygen Demand

Values were varied from 2.3 to 6.1 mg/L in the entire ground water samples during pre-monsoon season. A maximum value of 6.4 mg/L was monitored in sample GWS/Dheepri Chambal/2013-14.

Heavy Metals

Heavy metal is like Fe, Cd, Cu, Zn, Mn and Pb were analyzed during pre-monsoon period for successive three years. Heavy metals like Cd, Cu, Mn and Zn were ND and those samples have some values of these metals were under permissible limits of IS 10500 and WHO.

CALCULATED INDICES

Aggressive Index (AI): Calculated values of aggressive index for all the samples analyzed in successive three years was ranged from 11.71 to 13.62 with an overall average of 12.70.

Langelier Saturation Index (LSI)

A calculated value of langelier saturation index (LSI) was varied from -1 to 0.94 with an overall average of 0.041 for all the samples analyzed in successive three years. Use of groundwater without any treatment may result in such manner; only 5 sample result in slight corrosion, 4 samples result in faint scale coating, 3 samples result in slight scale/encrustation and remaining samples result in mild scale/ encrustation. Data reveals that nature of groundwater samples of study area were neither severe corrosive nor severe scale/encrustation but usually mild conditioning is required.

Percentage Sodium (% Na)

Calculated values of percentage sodium (%Na) were ranged from 56.68 to 68.07 with overall average of 61.95 for all the samples analyzed in successive three years. The minimum value was found in sample GWS/Binayaka during 2011-12. Use of water having excess sodium percentage is not suitable not suitable for irrigational purpose. Data reveals that 6 samples were in permissible class and use of 12 ground water samples was doubtful.

Sodium Adsorption Ratio (SAR)

The calculated values of sodium adsorption ratio (SAR) were ranged from 4.23 to 5.58 with overall average of 4.81for all the samples analyzed in successive three years. Classification of groundwater samples as per US agricultural norms reveals that all samples were of low (S_1) class.

Residual Sodium Carbonate (RSC)

The calculated values of residual sodium carbonates (RSC) were ranged from 0.59 to 4.42 with overall average of 3.05 for all the samples analyzed in successive three years. Maximum value of RSC was calculated in sample GWS/Talab 2011 and minimum value was in sample GWS/Binayaka-2011-12.

Exchangeable Sodium Percentage (ESP)

The calculated values of exchangeable sodium percentage (ESP) were ranged from 4.75 to 6.52 with overall average of 5.51 for all the samples analyzed in successive three years. Maximum value of ESP was calculated in sample GWS/Talab-2013-14 and minimum value was in sample GWS/Ganeshganj-2011-12.

Table: 8

Physico-Chemical Parameters of Groundwater of Itawa Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Binayak (GWS) I1-Morning I2-Evening	2011-12	Pre Monsoon	Morning	8.7	1256	908	378	ND	378	311	185	125	199	9.6	135	155	32	1.1
			Evening	8.8	1160	900	330	ND	330	323	194	129	198	10.2	141	201	34	1.5
		Post Monsoon	Morning	7.7	880	701	203	13	190	152	86	65	103	1.2	65	75	21	0.7
			Evening	8.4	804	693	152	ND	152	161	93	69	107	1.3	86	99	25	0.8
		Winter	Morning	8.2	1084	774	292	ND	292	271	156	116	136	3.1	99	112	29	0.9
			Evening	8.6	964	768	232	ND	232	231	132	99	147	3.1	115	129	31	1.1
		Spring	Morning	8.6	1224	839	362	ND	362	303	181	122	189	3.9	129	145	30	1
			Evening	8.7	1186	832	343	ND	343	318	189	129	185	3.8	139	152	34	1.4
	2012-13	Pre Monsoon	Morning	9.1	1316	933	408	ND	408	352	208	143	190	7.1	130	152	30	1.2
			Evening	8.9	1092	923	296	ND	296	243	151	93	200	7.2	143	155	36	1.2
		Post Monsoon	Morning	8.1	998	727	249	ND	249	212	121	90	97	2.6	60	72	19	1
			Evening	8.4	846	719	173	ND	173	73	42	31	133	2.8	67	77	23	0.8
		Winter	Morning	8.2	1212	788	356	ND	356	287	152	135	156	4.9	99	112	26	1.1
			Evening	8.6	976	781	238	ND	238	174	111	63	166	5	113	121	22	1.1
		Spring	Morning	8.7	1456	853	363	ND	363	337	199	139	173	6.2	129	149	29	1.2
			Evening	8.8	1050	847	275	ND	275	214	140	74	181	6.4	125	137	30	1.1
	2013-14	Pre Monsoon	Morning	9.3	1078	891	289	ND	289	242	151	92	196	7.6	140	157	35	1.2
			Evening	8.9	1264	881	382	ND	382	329	193	136	196	7.8	141	152	34	1.4
		Post Monsoon	Morning	8.0	802	689	159	8	151	119	84	35	127	2.4	86	98	29	0.9
			Evening	8.8	874	680	187	ND	187	137	86	51	141	2.5	96	103	24	1
		Winter	Morning	8.6	1012	755	256	ND	256	203	129	74	162	4.7	112	124	23	1.1
			Evening	9.0	1134	745	317	ND	317	247	148	99	175	4.6	122	120	26	1.2
		Spring	Morning	8.8	1042	823	271	ND	271	234	146	88	182	7	134	148	31	1.2
			Evening	9.2	1218	812	359	ND	359	321	189	132	187	7	138	151	32	1.3

Note: All Values Except pH & EC are in mg/L.

Table: 9

Physico-Chemical Parameters of Groundwater of Itawa Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Ayana (GWS) I3-Morning I4-Evening	2011-12	Pre Monsoon	Morning	7.9	1376	668	438	ND	438	236	160	76	166	6.7	51	70	27	1.3
			Evening	7.9	1452	667	476	ND	476	275	176	99	169	7.8	55	72	29	1.4
		Post Monsoon	Morning	7.5	976	463	238	ND	238	122	89	33	99	1.0	28	45	16	0.9
			Evening	7.5	990	462	245	ND	245	134	89	45	99	0.9	34	44	15	0.9
		Winter	Morning	7.7	1188	530	344	ND	344	191	135	56	132	2.6	40	56	26	1.2
			Evening	7.7	1198	528	349	ND	349	210	138	71	135	2.4	50	64	25	1.1
		Spring	Morning	7.9	1336	592	418	ND	418	228	157	71	159	3.2	51	63	27	1.3
			Evening	7.9	1408	591	454	ND	454	267	176	92	162	3.1	53	69	28	1.3
	2012-13	Pre Monsoon	Morning	8.1	1428	693	464	ND	464	267	176	91	172	6.0	58	68	39	1.5
			Evening	8.1	1416	691	458	ND	458	285	188	96	162	6.0	59	68	39	1.5
		Post Monsoon	Morning	7.6	992	491	258	12	246	114	89	26	109	1.9	36	37	22	1.1
			Evening	7.6	1126	488	313	ND	313	151	106	45	124	1.8	36	38	22	1.2
		Winter	Morning	7.9	1288	556	394	ND	394	202	124	78	146	4.4	41	47	28	1.3
			Evening	7.8	1296	552	398	ND	398	203	137	66	149	4.4	43	46	29	1.4
		Spring	Morning	8.0	1755	618	448	ND	448	255	172	84	166	5.6	56	63	36	1.4
			Evening	8.0	1404	613	452	ND	452	259	179	80	159	5.5	52	57	33	1.5
	2013-14	Pre Monsoon	Morning	8.1	1394	648	447	ND	447	271	180	91	170	6.4	63	75	41	1.7
			Evening	8.2	1432	644	466	ND	466	295	195	99	168	6.5	63	76	40	1.6
		Post Monsoon	Morning	7.6	984	445	242	ND	242	133	110	24	102	1.0	39	42	18	1.2
			Evening	7.7	1030	443	283	18	265	123	88	34	116	0.9	35	41	22	1.2
		Winter	Morning	7.8	1330	513	415	ND	415	231	155	77	150	3.4	42	62	28	1.4
			Evening	7.9	1282	512	391	ND	391	235	168	66	141	3.4	46	63	27	1.3
		Spring	Morning	8.0	1382	576	441	ND	441	264	174	90	164	5.2	58	69	37	1.8
			Evening	8.0	1412	573	456	ND	456	280	188	92	158	5.1	54	65	35	1.6

Note: All Values Except pH & EC are in mg/L.

Table: 10

Physico-Chemical Parameters of Groundwater of Itawa Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Ganeshganj (GWS) I5-Morning I6-Evening	2011-12	Pre Monsoon	Morning	7.7	1446	779	473	ND	473	216	130	85	185	4.8	41	63	34	1.0
			Evening	7.9	1456	780	478	ND	478	224	138	86	186	4.9	43	63	37	1.0
		Post Monsoon	Morning	7.5	1294	639	399	2	397	176	119	57	156	3.0	31	52	28	1.0
			Evening	7.4	1014	574	257	ND	257	83	49	33	107	1.3	19	22	12	0.8
		Winter	Morning	7.7	1412	694	456	ND	456	211	128	83	179	3.9	40	61	35	1.0
			Evening	7.6	1214	639	357	ND	357	173	106	66	146	3.1	40	56	27	0.9
		Spring	Morning	7.9	1390	805	445	ND	445	239	145	94	186	6.6	67	74	43	1.3
			Evening	7.8	1406	695	453	ND	453	205	125	79	182	3.9	42	60	37	1.1
	2012-13	Pre Monsoon	Morning	7.4	1020	601	260	ND	260	97	65	31	126	2.3	32	45	27	1.0
			Evening	8.0	1434	808	467	ND	467	215	133	81	182	6.6	40	61	36	1.2
		Post Monsoon	Morning	7.6	1224	663	368	6	362	165	106	59	156	5.0	49	52	30	1.2
			Evening	7.5	958	603	229	ND	229	84	45	39	92	2.2	17	21	12	1.0
		Winter	Morning	7.7	1356	721	428	ND	428	213	133	79	178	6.6	59	65	36	1.3
			Evening	7.7	1188	666	344	ND	344	128	87	41	149	5.0	34	42	27	1.1
		Spring	Morning	7.9	1428	755	464	ND	464	248	152	96	189	7.2	65	72	46	1.4
			Evening	7.8	1410	722	455	ND	455	204	126	78	179	6.7	39	61	36	1.2
	2013-14	Pre Monsoon	Morning	7.5	968	551	234	ND	234	70	57	14	112	2.1	27	31	16	0.6
			Evening	8.0	1462	759	481	ND	481	224	139	85	192	7.3	46	70	40	1.3
		Post Monsoon	Morning	7.8	1234	619	367	ND	367	161	108	53	169	4.2	54	61	30	1.3
			Evening	7.6	1068	553	284	ND	284	91	56	36	124	2.1	23	32	17	0.9
		Winter	Morning	7.8	1234	619	367	ND	367	161	108	53	169	4.2	54	61	30	1.3
			Evening	7.8	1126	621	313	ND	313	121	85	35	149	4.4	38	55	31	1.1
		Spring	Morning	7.9	1372	676	436	ND	436	233	140	93	179	6.0	64	70	38	1.4
			Evening	8.0	1412	677	456	ND	456	209	128	81	185	6.3	42	69	38	1.3

Note: All Values Except pH & EC are in mg/L.

Table: 11

Physico-Chemical Parameters of Groundwater of Itawa Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Rajopa (GWS) I7-Morning I8-Evening	2011-12	Pre Monsoon	Morning	6.1	1556	1308	528	ND	528	348	212	137	210	9.2	97	121	32	1.6
			Evening	6.2	1560	1276	530	ND	530	354	214	140	211	11.4	98	125	33	1.8
		Post Monsoon	Morning	5.6	1176	1096	338	ND	338	170	95	75	152	10.3	45	92	21	0.6
			Evening	5.7	1140	1065	320	ND	320	147	80	67	148	14.0	41	90	20	1.1
		Winter	Morning	5.8	1396	1158	448	ND	448	270	160	110	174	12.0	63	104	24	1.4
			Evening	5.9	1386	1126	443	ND	443	257	158	99	169	15.9	59	96	21	1.5
		Spring	Morning	6.0	1520	1216	510	ND	510	324	201	123	198	12.7	83	116	28	1.5
			Evening	6.1	1552	1184	526	ND	526	329	204	125	200	16.5	81	117	27	1.7
	2012-13	Pre Monsoon	Morning	6.2	1590	1330	545	ND	545	361	219	143	209	14.9	94	123	35	1.9
			Evening	6.3	1588	1297	544	ND	544	357	210	147	204	18.6	89	119	36	1.7
		Post Monsoon	Morning	5.8	1190	1123	369	24	345	192	106	87	143	10.2	40	94	21	1.1
			Evening	5.9	1130	1091	315	ND	315	138	74	64	142	13.8	39	78	17	1.1
		Winter	Morning	6.0	1418	1192	459	ND	459	278	164	114	173	12.5	60	101	24	1.6
			Evening	6.1	1352	1159	426	ND	426	243	152	91	170	16.2	62	96	23	1.5
		Spring	Morning	6.1	1540	1250	520	ND	520	334	200	134	201	14.0	90	113	30	1.9
			Evening	6.3	1538	1218	519	ND	519	323	199	125	199	17.6	80	119	27	1.8
	2013-14	Pre Monsoon	Morning	6.3	1606	1290	553	ND	553	370	219	151	215	15.7	99	126	38	1.9
			Evening	6.4	1614	1256	557	ND	557	337	200	137	209	19.3	81	116	29	1.8
		Post Monsoon	Morning	5.8	1198	1085	349	ND	349	188	100	88	147	10.0	46	89	17	1.1
			Evening	5.9	1108	1050	314	10	304	119	69	50	140	13.5	35	70	17	1.1
		Winter	Morning	6.1	1438	1156	469	ND	469	273	162	111	169	12.4	54	90	21	1.4
			Evening	6.1	1372	1121	436	ND	436	235	149	86	168	16.0	56	85	19	1.6
		Spring	Morning	6.2	1550	1215	525	ND	525	335	202	134	207	14.0	94	113	32	1.7
			Evening	6.3	1542	1179	521	ND	521	323	196	127	195	17.5	76	110	29	1.8

Note: All Values Except pH & EC are in mg/L.

Table: 12

Physico-Chemical Parameters of Groundwater of Itawa Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Talab (GWS) I9-Morning I10-Evening	2011-12	Pre Monsoon	Morning	7.7	1102	694	301	ND	301	170	98	64	138	9.3	55	70	26	1.6
			Evening	7.9	1104	692	302	ND	302	183	101	73	140	9.6	61	76	29	1.7
		Post Monsoon	Morning	7.3	776	480	138	ND	138	34	39	27	75	6.0	31	40	17	0.9
			Evening	7.4	760	478	144	14	130	38	30	30	77	6.5	34	44	16	1.1
		Winter	Morning	7.5	964	553	232	ND	232	95	54	33	123	7.5	40	54	23	1.4
			Evening	7.7	802	551	151	ND	151	74	44	22	100	8.3	42	59	23	1.6
		Spring	Morning	7.6	1074	603	287	ND	287	151	86	57	131	8.1	48	60	25	1.6
			Evening	7.8	1074	601	287	ND	287	155	82	64	134	9.0	52	64	26	1.7
	2012-13	Pre Monsoon	Morning	7.9	1124	720	312	ND	312	184	109	67	141	11.1	58	68	36	1.7
			Evening	8.1	1076	718	288	ND	288	176	98	69	139	11.6	62	73	39	1.6
		Post Monsoon	Morning	7.4	808	506	154	ND	154	44	47	40	75	6.5	33	37	21	1.1
			Evening	7.7	700	505	100	ND	100	32	35	30	67	7.1	40	41	24	1.0
		Winter	Morning	7.6	994	579	247	ND	247	110	57	44	130	9.2	43	60	30	1.5
			Evening	7.9	796	579	148	ND	148	85	46	30	93	9.9	47	50	28	1.3
		Spring	Morning	7.8	1088	629	294	ND	294	149	80	60	140	10.5	53	60	33	1.6
			Evening	8.0	990	630	245	ND	245	161	87	65	123	11.3	60	68	39	1.5
	2013-14	Pre Monsoon	Morning	7.9	1144	673	322	ND	322	193	112	73	145	11.4	57	74	39	1.8
			Evening	8.1	1120	671	310	ND	310	196	111	76	144	11.8	63	76	42	1.9
		Post Monsoon	Morning	7.5	798	459	155	6	149	51	45	37	82	6.2	39	40	28	1.2
			Evening	7.7	684	458	92	ND	92	54	28	17	75	6.5	41	44	24	1.3
		Winter	Morning	7.7	1004	532	252	ND	252	110	62	40	131	8.8	41	58	30	1.5
			Evening	7.9	810	532	155	ND	155	106	61	37	98	9.2	50	69	31	1.5
		Spring	Morning	7.9	1104	584	302	ND	302	159	85	65	141	10.5	52	63	35	1.7
			Evening	8.1	1034	586	267	ND	267	156	83	64	137	11.0	60	70	39	1.8

Note: All Values Except pH & EC are in mg/L.

Table: 13

Physico-Chemical Parameters of Groundwater of Itawa Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Dheepri Chambal (GWS) I11-Morning I12-Evening	2011-12	Pre Monsoon	Morning	8.6	1000	980	250	ND	250	465	260	205	154	15.1	210	220	58	0.9
			Evening	8.6	1124	976	312	ND	312	493	266	227	174	13.4	212	242	35	0.8
		Post Monsoon	Morning	8.1	618	771	59	ND	59	145	99	47	98	11.4	120	121	27	0.4
			Evening	8.2	880	768	190	ND	190	251	135	116	106	9.4	125	107	23	0.4
		Winter	Morning	8.4	828	840	164	ND	164	308	175	133	120	13.1	145	185	34	0.6
			Evening	8.4	942	836	221	ND	221	359	190	169	136	11.0	151	198	36	0.7
		Spring	Morning	8.5	882	888	191	ND	191	408	217	191	138	14.0	198	205	54	0.9
			Evening	8.6	1098	884	299	ND	299	456	252	204	168	11.8	196	236	23	0.8
	2012-13	Pre Monsoon	Morning	8.7	1072	1009	286	ND	286	489	275	214	175	16.3	221	236	61	1.2
			Evening	8.7	1114	1004	307	ND	307	471	255	216	191	14.1	217	244	49	0.9
		Post Monsoon	Morning	8.3	608	793	76	22	54	133	99	35	107	12.0	121	125	33	0.7
			Evening	8.2	840	788	170	ND	170	238	137	101	109	10.0	131	110	24	0.3
		Winter	Morning	8.5	934	869	217	ND	217	332	182	150	150	14.6	156	198	44	1.1
			Evening	8.5	918	865	209	ND	209	342	182	160	129	12.7	147	190	32	0.8
		Spring	Morning	8.8	1060	918	280	ND	280	465	256	209	168	16.4	206	225	59	1.2
			Evening	8.6	1058	915	279	ND	279	449	243	206	174	14.4	206	236	42	0.9
	2013-14	Pre Monsoon	Morning	8.8	1084	966	292	ND	292	533	297	237	187	17.0	232	279	69	1.3
			Evening	8.8	1134	960	317	ND	317	504	275	229	184	14.9	237	228	46	1.1
		Post Monsoon	Morning	8.4	626	750	63	ND	63	135	98	37	118	11.6	129	135	27	1.1
			Evening	8.3	782	744	141	ND	141	219	129	89	110	9.3	136	110	28	0.8
		Winter	Morning	8.6	942	825	221	ND	221	351	193	158	156	14.5	162	206	57	1.2
			Evening	8.6	1008	818	254	ND	254	351	185	167	156	12.1	157	193	40	0.9
		Spring	Morning	8.8	1044	873	272	ND	272	493	279	214	174	17.1	211	262	65	1.3
			Evening	8.7	1084	865	292	ND	292	459	252	207	178	14.6	231	212	34	1.1

Note: All Values Except pH & EC are in mg/L.

Table: 14

Heavy Metals Concentration and Some Physicochemical Analysis of ItawaTehsil

S. No.	Name of Location	Year	Parameters			Trace Heavy Metal						Data Interpretation					
			DO	BOD	COD	Fe	Cd	Cu	Zn	Mn	Pb	AI	LSI	%Na	SAR	RSC	ESP
1	Binayaka (GWS)	2011-12	5.8	3.2	4.1	0.14	ND	ND	0.01	ND	0.31	13.32	0.61	56.68	4.25	0.59	4.76
		2012-13	5.4	2.2	4.4	0.13	ND	ND	0.03	0.01	0.34	13.43	0.73	60.21	4.83	1.17	5.51
		2013-14	5.3	3.7	4.6	0.13	ND	ND	0.02	ND	0.32	13.62	0.94	62.07	5.00	0.95	5.76
2	Ayana (GWS)	2011-12	6.1	3.2	3.4	0.17	ND	0.01	ND	ND	0.28	13.01	0.35	58.82	4.31	1.72	4.84
		2012-13	6.7	3.2	3.8	0.16	ND	0.03	ND	0.02	0.29	13.05	0.39	64.49	5.15	2.48	5.95
		2013-14	6.8	3.8	3.5	0.11	ND	0.04	0.13	ND	0.21	13.36	0.70	59.23	4.54	2.14	5.16
3	Ganeshganj (GWS)	2011-12	6.5	2.7	5.1	0.12	ND	ND	0.12	ND	ND	12.62	-0.01	59.38	4.23	3.25	4.75
		2012-13	6.4	2.5	5.2	0.17	ND	ND	0.11	0.03	ND	12.79	0.15	59.81	4.42	3.59	5.00
		2013-14	6.3	2.1	5.3	0.14	ND	ND	0.18	ND	0.41	12.82	0.21	58.34	4.24	3.23	4.76
4	Rajopa (GWS)	2011-12	5.7	1.4	5.8	0.15	ND	ND	0.19	0.07	0.38	12.53	-0.13	62.20	4.73	3.86	5.40
		2012-13	5.1	1.5	5.9	0.16	ND	ND	0.21	ND	0.42	12.61	-0.04	62.65	4.85	3.76	5.56
		2013-14	5.2	1.6	6.1	0.13	ND	ND	ND	ND	ND	12.70	0.06	62.72	4.86	3.59	5.57
5	Talab (GWS)	2011-12	5.4	1.7	4.1	0.14	ND	ND	ND	0.02	ND	12.42	-0.26	66.49	5.27	4.42	6.12
		2012-13	6.3	1.8	4.3	0.11	ND	ND	ND	ND	ND	12.45	-0.23	66.81	5.29	4.11	6.14
		2013-14	6.2	2.1	3.7	0.09	ND	ND	ND	0.01	ND	12.59	-0.07	68.07	5.58	4.20	6.52
6	Dheepri Chambal (GWS)	2011-12	6.3	2.4	2.6	0.14	ND	ND	0.12	ND	0.21	11.71	-1.00	62.50	5.03	3.94	5.80
		2012-13	6.8	2.2	2.7	0.12	ND	ND	0.15	ND	0.22	11.82	-0.88	61.89	4.93	3.92	5.67
		2013-14	6.4	2.3	2.3	0.16	ND	ND	0.13	0.05	0.25	11.92	-0.77	62.90	5.20	4.05	6.02

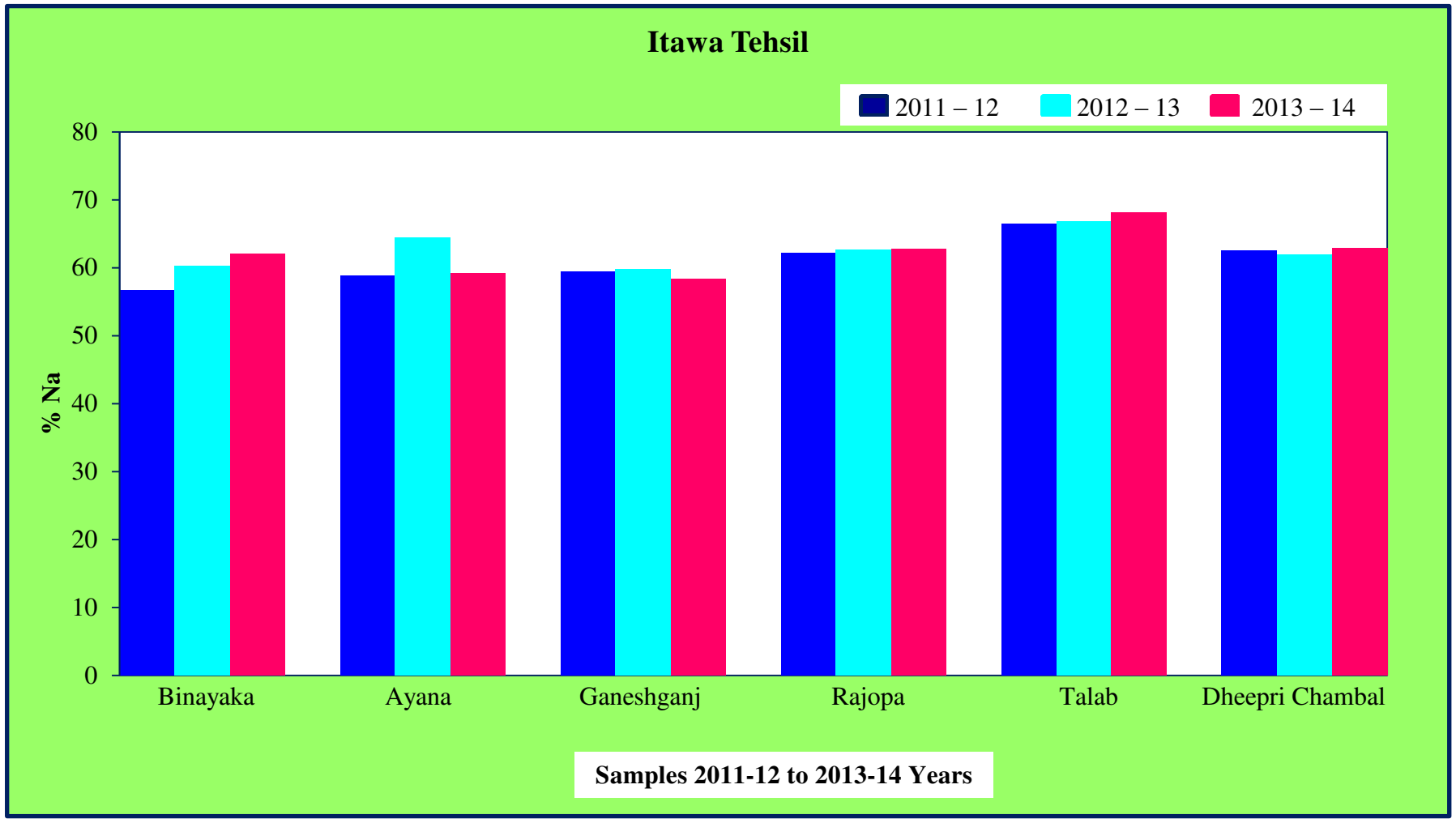

Fig 2A: Comparative Study of %Na in Itawa Tehsil for Three Years

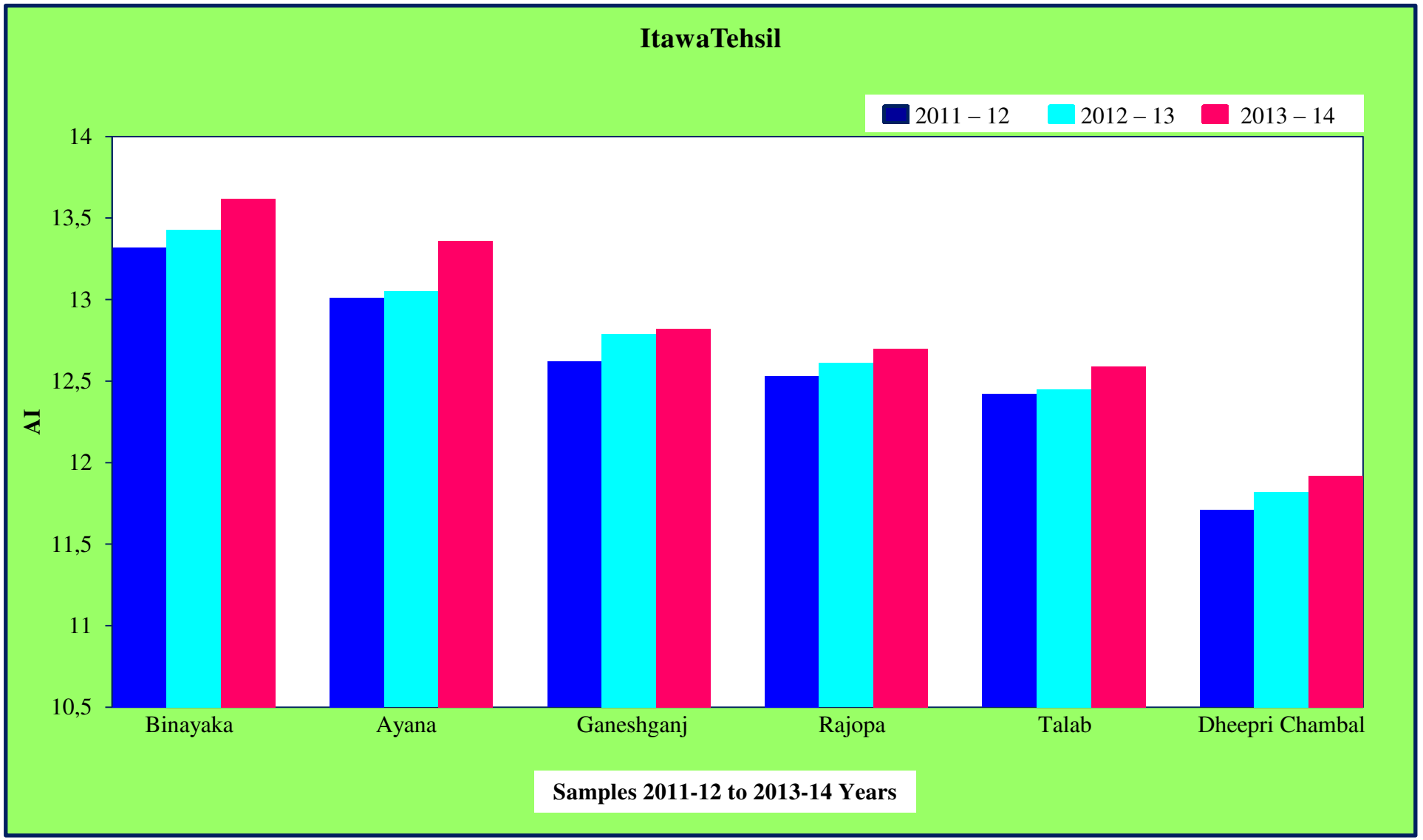

Fig 2B: Comparative Study of AI in Itawa Tehsil for Three Years

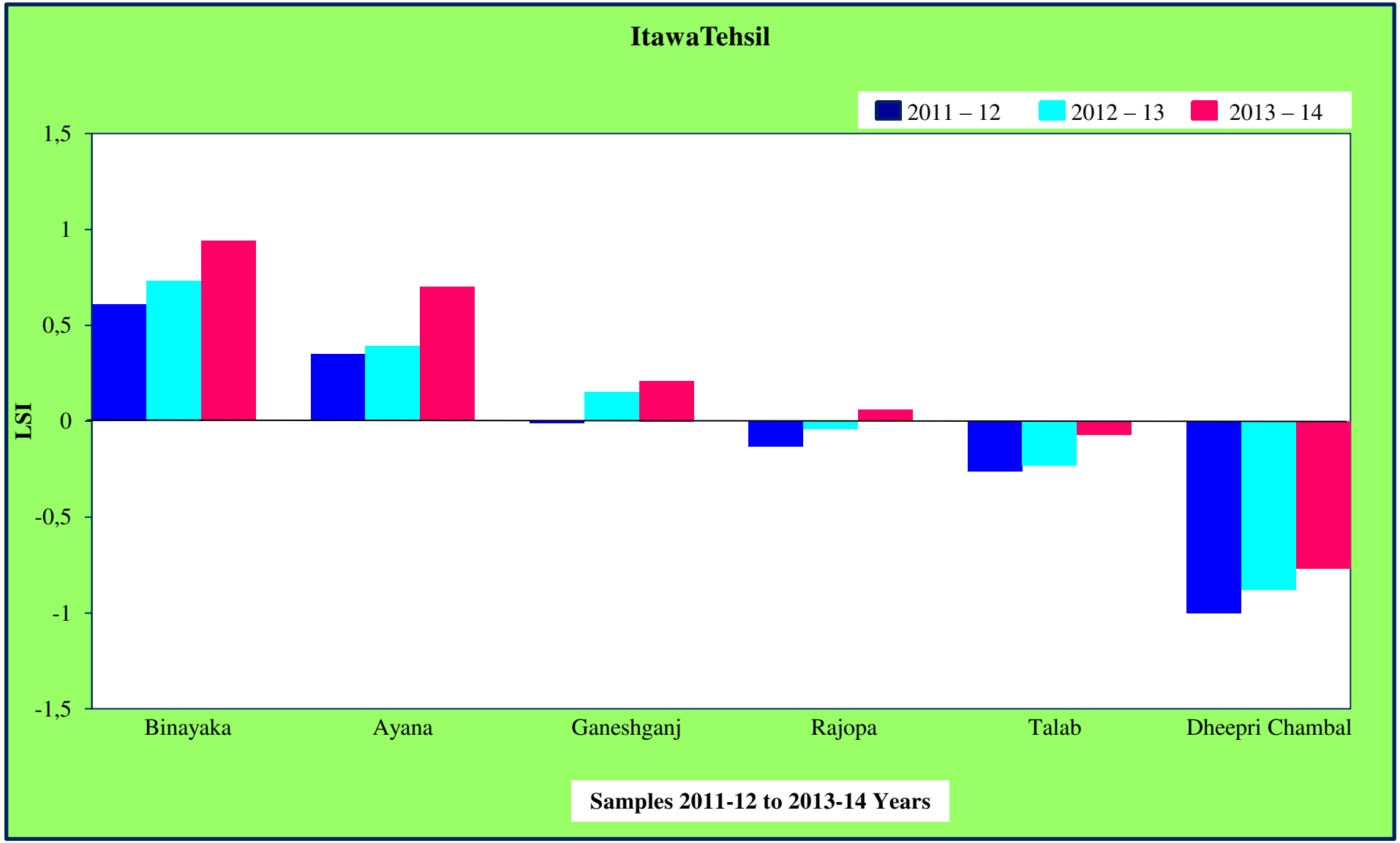

Fig 2C: Comparative Study of LSI in Itawa Tehsil for Three Years

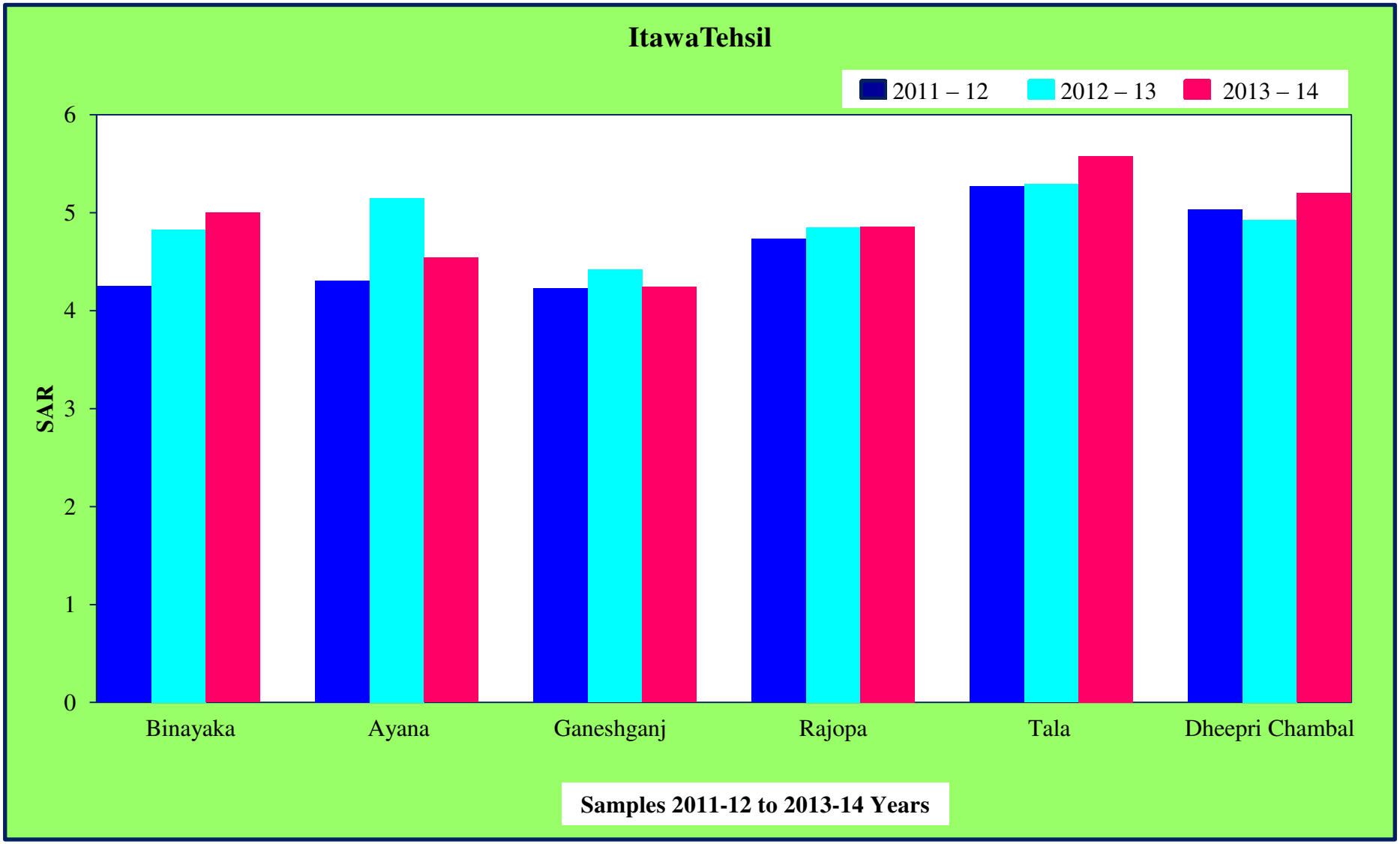

Fig 2D: Comparative Study of SAR in Itawa Tehsil for Three Years

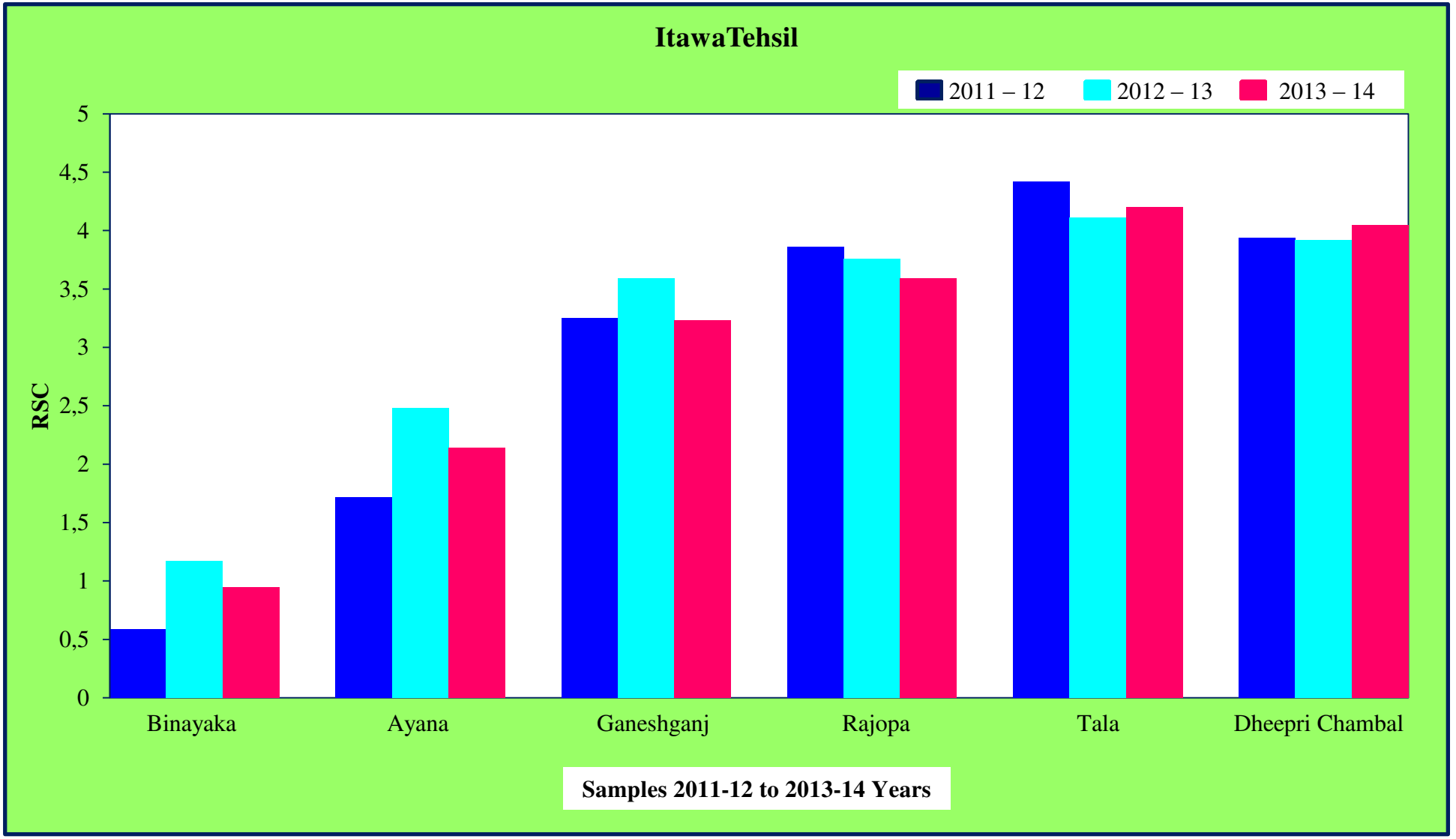

Fig 2E: Comparative Study of RSC in Itawa Tehsil for Three Years

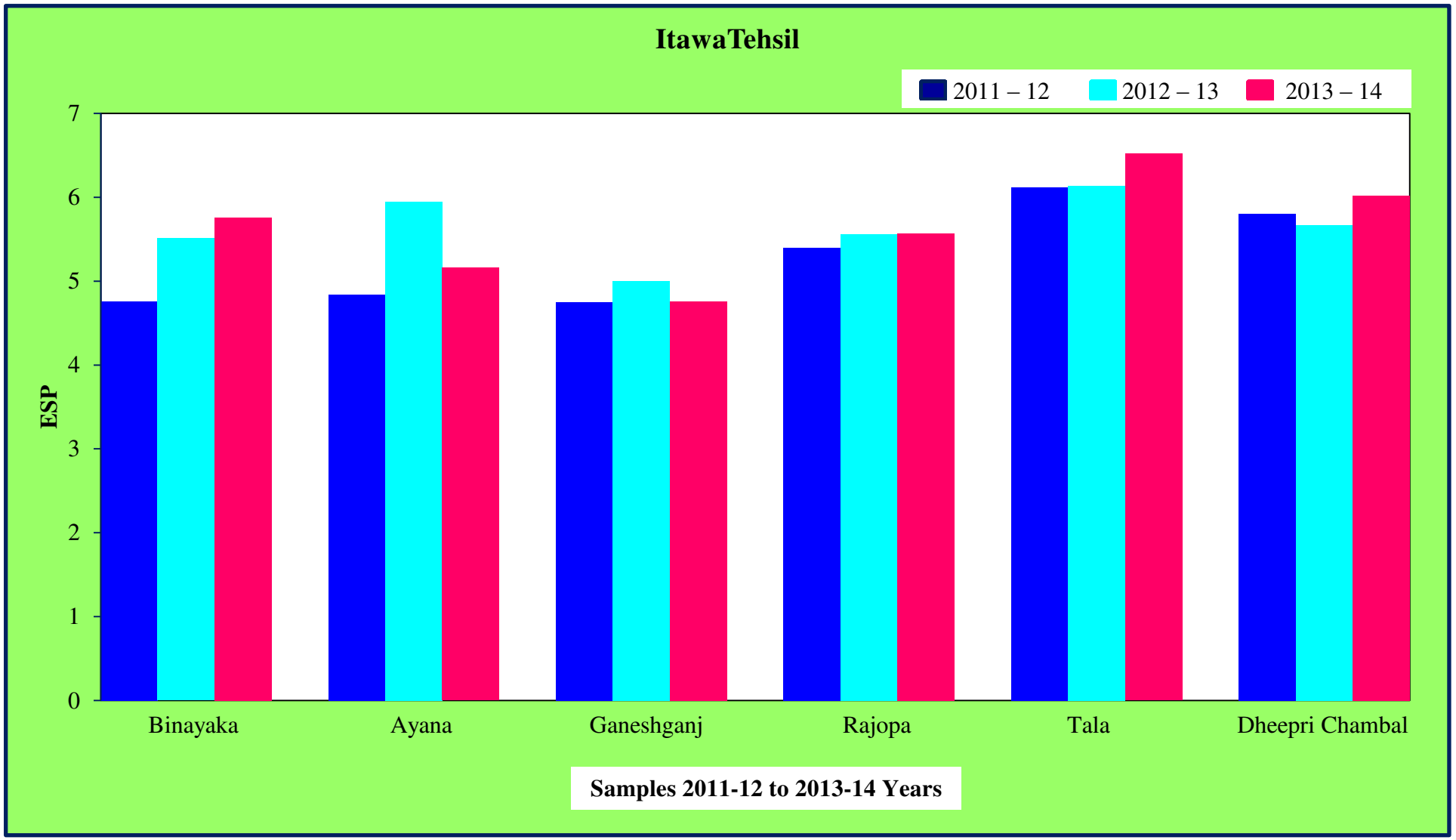

Fig 2F: Comparative Study of ESP in Itawa Tehsil for Three Years

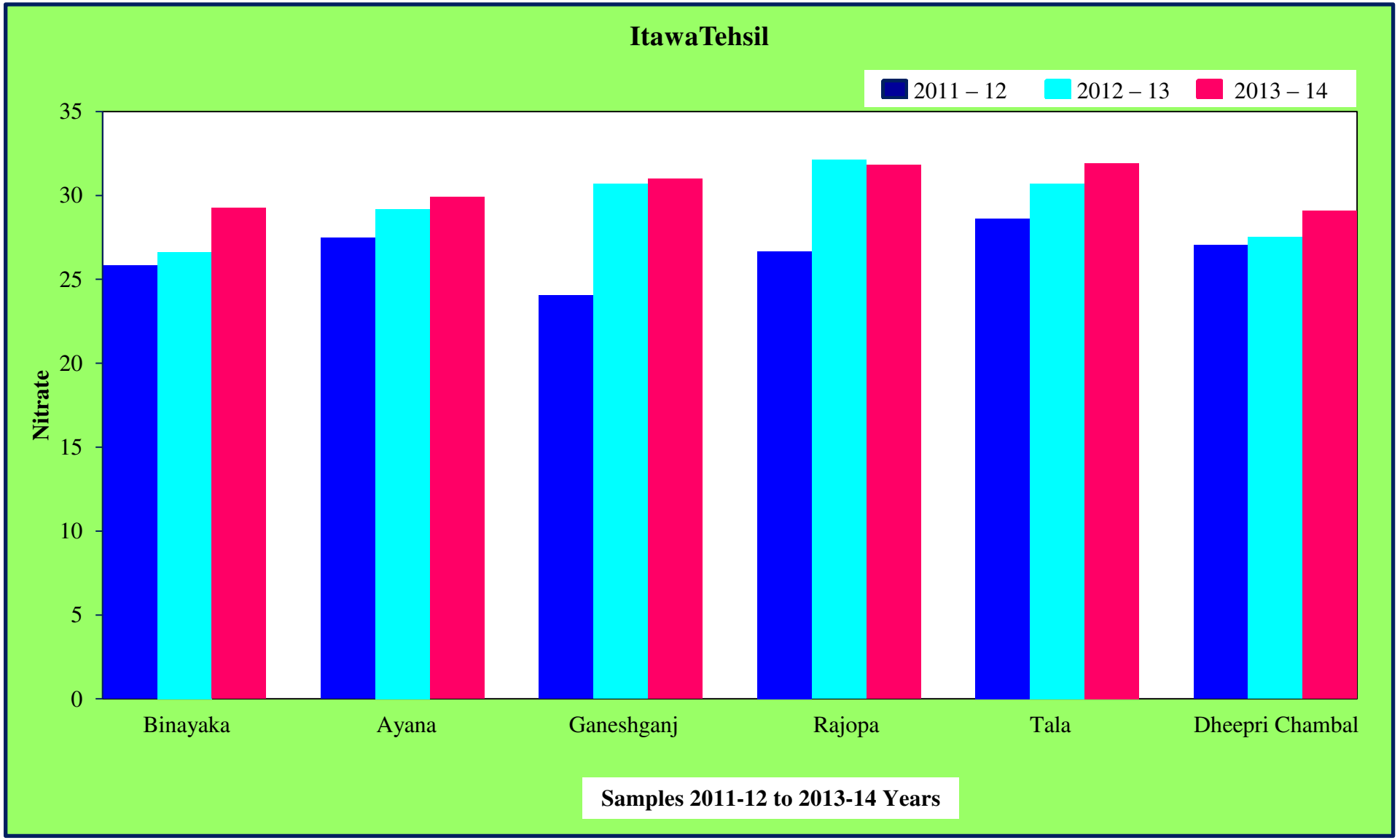

Fig 2G: Comparative Study of Nitrate in Itawa Tehsil for Three Years

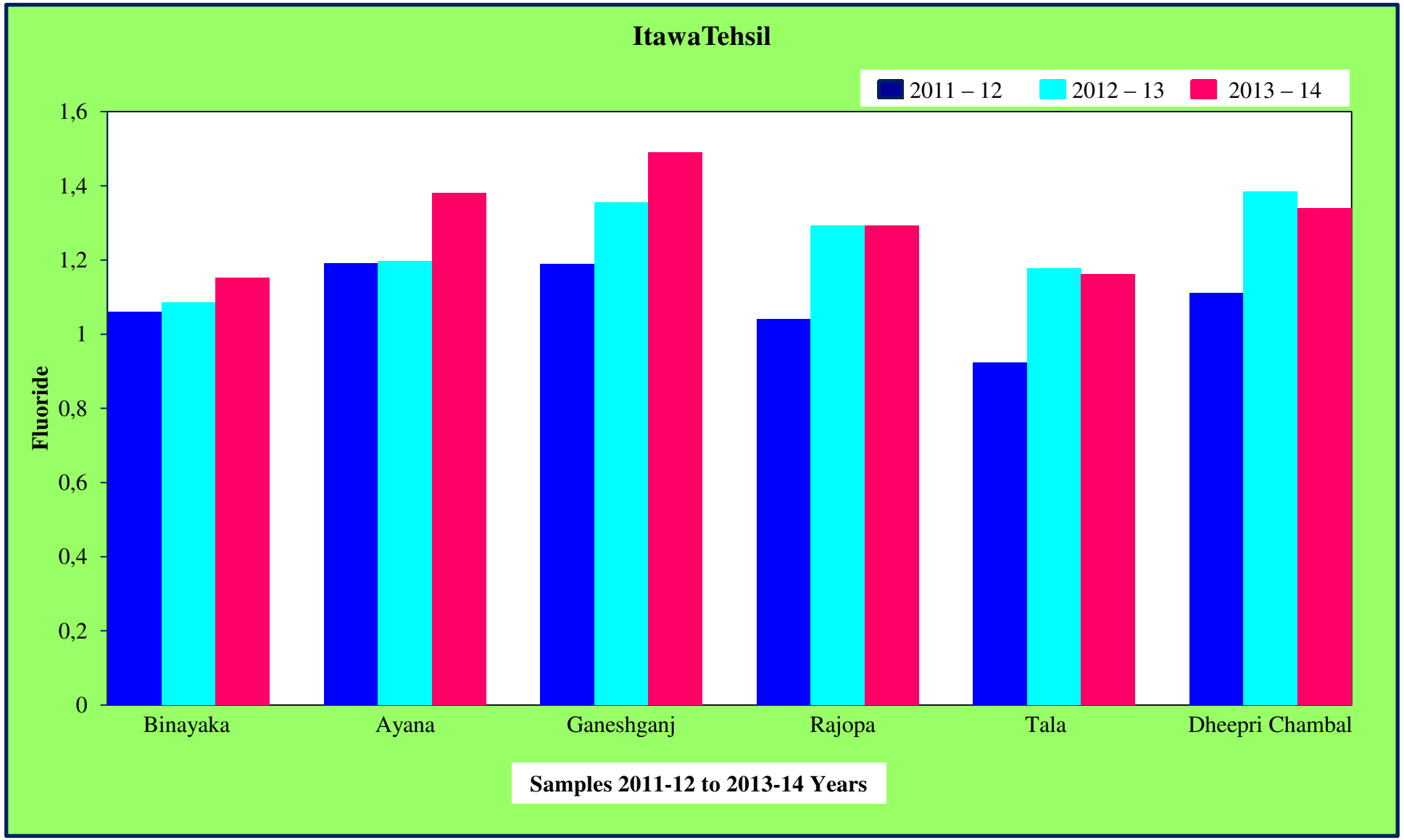

Fig 2H: Comparative Study of Fluoride in Itawa Tehsil for Three Years

LADPURA TEHSIL

The quantitative analysis of physicochemical parameters of six village of each tehsil of Kota district for the three years (from April, 2011 to March 2014) during four seasons (pre-monsoon, post-monsoon winter and spring) in morning and evening time period are shown in Table no - 15 to 20, analysis of heavy metals and of some others physicochemical parameters are presented in Table No – 21 and comparative studies are represented by Fig No – 3A to 3H.

WATER QUALITY PARAMETERS

pH Values

The permissible limit of pH values for drinking water is specified as 6.5 to 8.5 as per IS 10500. The pH values of groundwater samples were ranged from 7.1 (GWS/L/9-2011-12/post monsoon) to 8.6 (GWS/L/10-2012-13/pre-monsoon & 2013-14/ pre-monsoon and spring) with overall average value 7.87 in successive three years analysis, out of 144 samples only 03 samples have higher value than permissible limit. The variables in pH values may be due to increase or decreases of human and other biological activities.

Conductance

The values of conductance of groundwater samples are ranged from 500 (GWS/L/10-2013-14/post-monsoon) to 2153 µS (GWS/L/2-2011-12/pre-monsoon) with overall average value 1227.9 µS of successive three years analysis, lower conductance in post monsoon period is due to dilution from rainwater.

Total Dissolved Solids

Normally ground water has a higher total dissolved solids load compared to surface water. Water of high TDS is not suitable for use in boilers and hence restricted industrial use. The TDS of groundwater samples ranged from 307 (GWS/L/10-2013-14/post-monsoon) to 1326 (GWS/L/2-2012-13/pre-monsoon) mg/L with an average value of 763.1 mg/L. High TDS values observed in pre-

monsoon season due to water concentrated. Lower values in post –monsoon was found due dilution of water with rainwater.

Total Alkalinity

According to IS 10500 the maximum allowable concentration of total alkalinity for drinking water is 600 mg/L. Total alkalinity of groundwater samples varies from 105 (GWS/L/2-2011-12/post-monsoon) mg/L to 714 (GWS/L/9-2013-14/Pre-monsoon) mg/L with overall average of 409.7 mg/L of successive three years analysis. Only 08 samples have higher values than the permissible limit of drinking water standard IS 10500.

Carbonate Alkalinity

In maximum number of analyzed samples carbonates alkalinity ND (Non detectable) and only in 10 samples carbonates alkalinity was detected. The values varied between 2 to 22 mg/L. The minimum value was observed in (GWS/L/1-2013-14/spring) and maximum in (GWS/L/3-2012-13/post-monsoon).

Bicarbonates Alkalinity

Bicarbonates alkalinity ranged from 105 to 714 mg/L with an overall average of 409.4 mg/L in analyzed samples during successive three years. In sample GWS/L/2-2011-12/post-monsoon minimum value of bicarbonates alkalinity was observed and in sample GWS/L/10-2013-14/pre- monsoon maximum value of bicarbonates alkalinity was observed.

Total hardness

The anions responsible for hardness are bicarbonates, carbonates, sulphate and chloride. Hardness is temporary if it is associated mainly with carbonates and bicarbonates, and permanents if with sulphate and chloride. The total hardness of groundwater samples ranged from 186 (GWS/L/9-2011-12/post-monsoon) to 671 (GWS/L/7-2013-14/pre-monsoon) mg/L with overall average of 439.3 mg/L of successive three years analysis.

Calcium Hardness

Calcium is important ion in imparting the hardness to the waters. At high pH much of its quantities may get precipitated as calcium carbonate. The calcium hardness of groundwater samples ranged from 66 to 340 mg/L with overall average of 232.58 mg/L of successive three years analysis. There is no definite trend in values of calcium hardness samples.

Magnesium Hardness

Magnesium also occurs in all kind of natural waters, but its concentration remains generally lower than the calcium hardness. The magnesium hardness ranged from 16 to 322 mg/L with overall average of 177.1 mg/L of successive three years analysis. Magnesium is determined as the difference between the total hardness and calcium hardness.

Sodium

Sodium values ranged from 77 to 247 mg/L and the average values of sodium was 164.6 mg/L in all of the studied samples of successive three- years. The maximum value of sodium examined in sample GWS/L/11-2013-14/pre-monsoon and the minimum value of sodium measured in sample GWS/L/10-2011-12/post-monsoon.

Potassium

Potassium values ranged from 1.2 to 17.8 mg/L and the average value of potassium was 7.64 mg/L in all of the studied samples of successive three-years. The maximum value of potassium examined in sample GWS/L/5-2013-14/pre-monsoon.

Chloride

The most important source of chloride in natural waters is the discharge of sewage. The values observed are within the specified limit of 250 mg/L as per IS 10500. The chloride concentration in groundwater samples varies from 15 to 215 mg/L with overall average of 137.2 mg/l of successive three years analysis.

Sulphate

The sulphate ion produces cathartic effect upon human beings when it is presents in excess. The higher values of sulphates content may be contributed due to bio chemical, anthropogenic sources and industrial process etc. The sulphate ion concentration in groundwater samples ranged from 1 to 210 mg/L with overall average of 127.1 mg/L of successive three years analysis. The maximum allowable limit of sulphates in drinking water as per IS 10500 is 400 mg/L.

Nitrate

The maximum allowable limit of nitrate in drinking water as per IS 10500 is 45 mg/L. Nitrate content in groundwater samples varies from 24 to 77 mg/L with overall average of 52.68 mg/L of successive three years analysis.

Fluoride

The fluoride ion concentrations in the study were within the specified limit and ranged from 0.1 to 2.5 mg/L with overall average of 1.03 mg/L in successive three years analysis. Water containing high fluoride concentration is not suitable for drinking water purpose. As per IS 10500 maximum fluoride concentration in drinking water is 1.50 mg/L.

Dissolved Oxygen

The data table reveals that DO values were ranged from 2.1 to 4.8 mg/L for the entire ground water samples and no major variations found in these values. The minimum value of DO was observed in sample (GWS/Rangpur/2013-14 and GWS/Jakhora/2013-14) and maximum value in sample (GWS/Rangpur/2011-12).

Biological Oxygen Demand

Values ranged from 2.1 to 4.8 mg/L for the entire ground water samples. BOD was monitored in sample (GWS/Kalayakheri/2012-13 and GWS/Alaniya/2012-13) as minimum value and BOD was monitored in samples (GWS/Girdharpura/2013-14) as maximum values.

Chemical Oxygen Demand

Values were varied from 2.5 to 3.3 mg/L in the entire ground water samples during pre-monsoon season. A maximum value of 3.3 mg/L was monitored in sample (GWS/Girdharpura/2013-14).

Heavy Metals

Heavy metal is like Fe, Cd, Cu, Zn, Mn, and Pb were analyzed during for successive three years. Heavy metals like Cd, Cu, Mn and Zn were ND and those samples have some values of these metals were under permissible limits of IS 10500 and WHO. Fe values ranged from 0.02 to 0.19 mg/L. These values were within the prescribed limit. Pb was also ND at maximum sites except (GWS/ Rangpur), (GWS/ Girdharpura), (GWS/ Kasar) and (GWS/ Jakhora) where values ranged from 0.01 to 0.15 mg/L and these all values were under permissible limits of IS 10500 and WHO the recommended standards.

CALCULATED INDICES

Aggressive Index (AI): Calculated values of aggressive index for all the samples analyzed in successive three years was ranged from 12.73 to 13.31 with an overall average of 13.076.

Langelier Saturation Index (LSI)

A calculated value of Langelier saturation index (LSI) was varied from -0.1 to 0.64 with an overall average of 0.3567 for all the samples analyzed in successive three years. Use of groundwater without any treatment may result in such manner; only one sample result in slight corrosion, 12 samples result in faint scale coating, 5 samples result in slight scale/encrustation.

Percentage Sodium (% Na)

Calculated values of percentage sodium (%Na) were ranged from 36.07 to 51.56 with overall average of 42.86 for all the samples analyzed in successive three

years. The minimum value was found in sample GWS/Jakhora during 2013-14. Use of water having excess sodium percentage is not suitable for irrigational purpose. Data reveals that 5 samples were of good class, 13 samples were in permissible class.

Sodium Adsorption Ratio (SAR)

The calculated values of sodium adsorption ratio (SAR) were ranged from 2.49 to 4.33 with overall average of 3.389 for all the samples analyzed in successive three years. Classification of groundwater samples as per US agricultural norms reveals that all samples were of low (S_1) class.

Residual Sodium Carbonate (RSC)

The calculated values of residual sodium carbonates (RSC) were ranged from -3.08 to -0.9 with overall average of -1.86 for all the samples analyzed in successive three years. Maximum value of RSC was calculated in sample GWS/Kalyakheri-2012-13 and minimum value was in sample GWS/Rangpur-2011-12.

Exchangeable Sodium Percentage (ESP)

The calculated values of exchangeable sodium percentage (ESP) were ranged from 2.35 to 4.88 with overall average of 3.59 for all the samples analyzed in successive three years. Maximum value of ESP was calculated in sample GWS/Rangpur-2013-14 and minimum value was in sample GWS/Jakhora-2011-12.

Table: 15

Physico-Chemical Parameters of Groundwater of Ladpura Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Rangpur (GWS) L1-Morning L2-Evening	2011-12	Pre Monsoon	Morning	8.2	2115	1293	309	ND	309	415	304	141	188	5.8	211	205	54	1.1
			Evening	8.3	2132	1304	324	3	321	424	307	148	188	5.9	209	204	54	1.0
		Post Monsoon	Morning	7.8	1789	1091	125	ND	125	254	206	86	136	1.7	180	173	39	0.6
			Evening	7.9	1807	1101	105	ND	105	262	209	84	128	1.7	184	174	38	0.6
		Winter	Morning	8.0	1894	1151	180	ND	180	312	240	102	152	3.6	190	187	48	1.0
			Evening	8.0	1913	1162	187	ND	187	320	243	107	151	3.4	189	186	47	0.9
		Spring	Morning	8.2	1996	1218	249	ND	249	360	268	122	169	4.1	197	190	48	1.3
			Evening	8.2	2014	1229	257	ND	257	368	270	128	168	4.0	197	189	48	1.1
	2012-13	Pre Monsoon	Morning	8.4	2135	1316	405	ND	405	448	315	164	218	6.8	212	201	63	1.2
			Evening	8.4	2153	1326	418	ND	418	458	318	170	217	7.0	210	199	62	1.2
		Post Monsoon	Morning	7.9	1810	1110	187	ND	187	287	218	99	163	2.6	192	174	48	0.9
			Evening	8.0	1827	1121	201	ND	201	296	221	105	162	2.9	189	170	48	1.0
		Winter	Morning	8.1	1914	1177	274	ND	274	345	251	124	184	5.0	199	181	52	1.1
			Evening	8.2	1930	1187	289	ND	289	353	253	131	183	5.4	195	178	51	1.1
		Spring	Morning	8.3	2015	1240	338	ND	338	396	282	144	202	6.3	206	192	57	1.4
			Evening	8.3	2032	1250	354	ND	354	406	285	150	201	6.8	203	188	57	1.5
	2013-14	Pre Monsoon	Morning	8.4	2085	1275	419	ND	419	451	322	160	231	7.2	215	210	65	1.4
			Evening	8.5	2102	1286	433	ND	433	461	325	166	230	7.5	213	208	65	1.3
		Post Monsoon	Morning	7.9	1767	1074	201	ND	201	289	225	94	170	1.6	193	176	46	1.2
			Evening	8.0	1783	1083	217	ND	217	298	227	100	170	2.2	189	172	46	1.0
		Winter	Morning	8.1	1876	1137	269	ND	269	347	256	120	191	3.8	200	198	51	1.4
			Evening	8.2	1891	1147	285	ND	285	355	259	127	190	4.6	197	194	51	1.3
		Spring	Morning	8.2	1979	1204	359	2	357	400	288	142	212	5.4	206	196	58	1.6
			Evening	8.3	1993	1213	371	ND	371	409	289	149	212	6.3	203	194	59	1.6

Note: All Values Except pH & EC are in mg/L.

Table: 16

Physico-Chemical Parameters of Groundwater of Ladpura Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Girdharpura (GWS) L3-Morning L4-Evening	2011-12	Pre Monsoon	Morning	8.0	1449	887	415	ND	415	520	314	235	186	7.1	206	201	62	0.9
			Evening	7.7	1415	868	437	ND	437	521	315	235	181	6.8	195	190	57	0.7
		Post Monsoon	Morning	7.6	1119	681	251	ND	251	361	236	185	136	3.3	181	171	47	0.6
			Evening	7.3	1084	660	228	ND	228	363	225	168	122	3.1	169	158	41	0.5
		Winter	Morning	7.7	1228	750	339	ND	339	422	279	199	160	5.0	186	182	52	1.1
			Evening	7.5	1194	728	315	5	310	424	262	192	144	4.9	174	171	51	0.9
		Spring	Morning	7.9	1324	818	392	ND	392	471	292	231	175	5.7	194	191	57	1.7
			Evening	7.6	1290	795	382	ND	382	473	290	212	161	5.7	181	174	51	1.3
	2012-13	Pre Monsoon	Morning	8.1	1465	910	523	ND	523	561	332	259	217	8.3	207	196	70	1.1
			Evening	7.9	1432	892	545	ND	545	563	334	259	212	7.9	196	185	65	0.8
		Post Monsoon	Morning	7.7	1143	708	318	22	318	402	240	194	161	3.9	183	166	54	0.6
			Evening	7.4	1109	689	338	ND	338	405	240	195	157	3.4	173	155	49	0.4
		Winter	Morning	7.8	1249	774	405	ND	405	462	272	221	181	6.2	190	172	57	0.8
			Evening	7.6	1215	756	428	ND	428	466	274	221	177	5.6	179	160	52	0.5
		Spring	Morning	8.0	1344	837	456	ND	456	513	302	241	199	7.5	202	187	63	1.2
			Evening	7.8	1312	818	488	ND	488	517	305	242	194	7.1	187	174	58	1.0
	2013-14	Pre Monsoon	Morning	8.2	1403	862	532	ND	532	564	339	255	227	8.9	210	205	73	1.3
			Evening	7.9	1371	845	554	ND	554	566	340	255	223	8.6	200	194	68	0.9
		Post Monsoon	Morning	7.8	1077	656	315	ND	315	400	242	189	166	3.7	187	169	54	0.9
			Evening	7.5	1045	640	335	ND	335	401	242	189	161	3.3	176	159	48	0.6
		Winter	Morning	8.0	1180	724	384	ND	384	461	276	214	186	6.0	193	191	60	1.1
			Evening	7.7	1149	708	406	ND	406	462	276	215	181	5.7	182	179	55	0.9
		Spring	Morning	8.1	1280	782	458	ND	458	510	303	236	206	7.5	202	192	67	1.5
			Evening	7.8	1249	765	482	ND	482	511	304	238	201	7.3	191	181	62	1.2

Note: All Values Except pH & EC are in mg/L.

Table: 17

Physico-Chemical Parameters of Groundwater of Ladpura Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Alaniya (GWS) L5-Morning L6-Evening	2011-12	Pre Monsoon	Morning	8.0	1480	907	490	ND	490	570	302	297	166	15.7	183	178	61	0.7
			Evening	7.6	1153	729	467	ND	467	514	258	286	163	15.0	169	164	53	0.8
		Post Monsoon	Morning	7.5	1142	697	282	ND	282	413	212	232	105	12.6	157	146	45	0.4
			Evening	7.2	815	520	263	ND	263	359	170	220	103	11.8	142	132	37	0.4
		Winter	Morning	7.8	1258	760	367	ND	367	475	249	256	129	14.7	163	160	53	0.6
			Evening	7.4	930	582	348	ND	348	421	206	245	127	14.0	148	146	46	0.5
		Spring	Morning	7.9	1346	819	441	ND	441	525	277	278	145	15.5	169	162	54	0.9
			Evening	7.6	1018	640	420	ND	420	470	232	268	143	14.9	156	149	46	0.9
	2012-13	Pre Monsoon	Morning	8.1	1501	930	603	ND	603	618	326	322	195	17.0	184	171	69	0.8
			Evening	7.8	1175	753	578	ND	578	561	280	312	193	16.5	170	159	62	0.9
		Post Monsoon	Morning	7.7	1165	732	401	ND	401	461	234	257	140	12.7	159	141	51	0.5
			Evening	7.3	840	555	383	ND	383	406	191	245	139	12.3	145	127	44	0.5
		Winter	Morning	7.9	1280	792	490	ND	490	523	270	283	161	15.1	166	149	55	0.8
			Evening	7.5	953	616	480	6	474	467	227	270	160	14.8	152	134	48	0.7
		Spring	Morning	8.0	1374	851	551	ND	551	575	302	303	179	16.3	176	162	61	0.9
			Evening	7.7	1047	673	534	ND	534	521	260	291	178	15.9	162	147	54	0.9
	2013-14	Pre Monsoon	Morning	8.1	1448	886	611	ND	611	619	331	319	207	17.8	187	182	72	1.1
			Evening	7.8	1122	710	590	ND	590	563	286	308	204	17.4	173	168	64	1.1
		Post Monsoon	Morning	7.7	1111	681	402	ND	402	461	239	259	146	12.3	165	148	53	1.0
			Evening	7.4	787	504	373	ND	373	405	192	244	144	12.3	152	135	46	0.9
		Winter	Morning	7.9	1218	750	463	ND	463	522	272	281	168	14.8	175	173	59	1.1
			Evening	7.6	894	572	445	ND	445	467	230	267	165	14.9	160	158	52	1.1
		Spring	Morning	8.1	1297	807	533	ND	533	567	293	304	188	16.5	184	174	66	1.2
			Evening	7.8	971	630	511	ND	511	510	249	291	186	16.7	170	160	59	1.3

Note: All Values Except pH & EC are in mg/L.

Table: 18

Physico-Chemical Parameters of Groundwater of Ladpura Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Kasar (GWS) L7-Morning L8-Evening	2011-12	Pre Monsoon	Morning	7.9	1468	908	388	ND	388	626	262	244	140	11.5	164	158	53	0.7
			Evening	7.8	1476	910	365	ND	365	618	258	240	141	11.0	170	165	55	0.5
		Post Monsoon	Morning	7.4	1128	693	176	ND	176	471	174	178	80	7.9	140	131	36	0.4
			Evening	7.3	1135	696	150	ND	150	464	171	174	81	7.6	145	140	39	0.3
		Winter	Morning	7.6	1242	766	255	ND	255	530	207	203	103	10.2	147	144	46	0.9
			Evening	7.5	1248	770	237	4	233	523	203	200	104	10.0	152	150	49	0.9
		Spring	Morning	7.7	1325	824	313	ND	313	573	226	227	119	11.0	156	149	46	1.2
			Evening	7.6	1332	827	295	ND	295	566	223	223	119	10.7	163	155	49	1.4
	2012-13	Pre Monsoon	Morning	8.0	1481	934	491	ND	491	669	281	269	168	12.9	165	154	61	0.9
			Evening	7.9	1488	936	472	ND	472	660	275	265	169	12.6	171	155	63	0.6
		Post Monsoon	Morning	7.6	1141	734	291	ND	291	514	190	205	113	8.2	141	123	45	0.3
			Evening	7.5	1145	738	255	ND	255	506	185	201	113	7.8	151	133	48	0.1
		Winter	Morning	7.8	1251	807	377	ND	377	572	221	232	135	10.8	148	130	49	0.6
			Evening	7.7	1257	811	341	ND	341	564	217	227	135	10.2	158	140	52	0.3
		Spring	Morning	7.9	1339	866	435	ND	435	627	253	254	151	12.2	158	144	55	1.0
			Evening	7.8	1346	869	401	ND	401	618	252	249	151	11.5	169	155	58	0.6
	2013-14	Pre Monsoon	Morning	8.1	1440	886	504	ND	504	671	285	265	178	13.7	166	161	63	1.1
			Evening	8.0	1446	888	480	ND	480	662	280	262	179	13.5	171	167	66	0.7
		Post Monsoon	Morning	7.6	1115	677	303	ND	303	514	212	202	116	8.3	145	128	44	0.8
			Evening	7.5	1120	680	260	ND	260	506	187	199	116	7.9	151	134	47	0.5
		Winter	Morning	7.8	1218	749	353	ND	353	572	227	228	136	10.4	152	150	50	1.0
			Evening	7.7	1221	753	330	ND	330	565	221	225	137	10.2	158	155	52	0.8
		Spring	Morning	7.9	1292	810	427	ND	427	620	251	249	156	12.5	160	151	57	1.3
			Evening	7.9	1296	813	407	5	402	611	245	247	157	12.4	167	157	60	1.0

Note: All Values Except pH & EC are in mg/L.

Table: 19

Physico-Chemical Parameters of Groundwater of Ladpura Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Kalyakheri (GWS) L9-Morning L10-Evening	2011-12	Pre Monsoon	Morning	7.6	926	558	600	ND	600	390	251	168	139	5.5	42	37	39	0.7
			Evening	8.4	858	543	537	ND	537	351	206	175	136	6.3	48	44	41	0.9
		Post Monsoon	Morning	7.1	582	357	387	ND	387	227	185	72	80	2.2	15	6	24	0.3
			Evening	7.9	513	341	325	ND	325	186	138	78	77	2.8	21	11	27	0.4
		Winter	Morning	7.4	692	422	467	ND	467	291	211	110	102	4.2	23	19	33	0.7
			Evening	8.2	622	408	404	ND	404	250	165	115	99	4.7	29	26	36	0.7
		Spring	Morning	7.5	769	481	543	ND	543	342	236	137	118	5.1	30	22	34	0.9
			Evening	8.3	698	466	481	ND	481	302	190	143	116	5.4	35	28	36	1.1
	2012-13	Pre Monsoon	Morning	7.7	942	584	698	ND	698	426	277	179	169	7.6	43	34	47	0.8
			Evening	8.6	875	571	635	ND	635	386	231	184	166	8.2	50	38	50	1.1
		Post Monsoon	Morning	7.3	604	383	489	ND	489	263	211	82	114	3.0	20	1	31	0.5
			Evening	8.2	536	368	418	ND	418	221	163	88	110	3.7	27	9	33	0.7
		Winter	Morning	7.5	710	457	575	ND	575	326	233	124	134	5.3	28	10	34	1.0
			Evening	8.4	642	443	504	ND	504	285	186	129	131	5.8	36	19	37	1.1
		Spring	Morning	7.7	794	510	628	ND	628	377	256	150	152	6.6	40	25	40	1.5
			Evening	8.5	724	497	560	ND	560	336	210	156	148	6.9	47	32	43	1.5
	2013-14	Pre Monsoon	Morning	7.7	888	540	714	ND	714	431	274	187	179	8.3	45	40	50	0.9
			Evening	8.6	820	525	653	3	650	391	229	193	175	8.8	51	45	53	1.3
		Post Monsoon	Morning	7.3	568	322	514	ND	514	283	209	104	117	2.5	20	3	31	0.3
			Evening	8.2	500	307	443	ND	443	243	164	109	114	3.0	29	12	34	0.8
		Winter	Morning	7.6	679	398	585	ND	585	347	232	146	137	5.0	28	26	38	0.7
			Evening	8.5	612	382	511	ND	511	306	187	150	134	5.5	38	36	41	1.1
		Spring	Morning	7.7	766	462	663	ND	663	397	256	171	157	6.6	34	25	45	1.3
			Evening	8.6	696	445	588	ND	588	354	211	172	154	7.2	44	35	48	1.6

Note: All Values Except pH & EC are in mg/L.

Table: 20

Physico-Chemical Parameters of Groundwater of Ladpura Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Jakhora (GWS) L11-Morning L12-Evening	2011-12	Pre Monsoon	Morning	7.7	1292	807	450	ND	450	519	155	105	206	4.9	88	82	63	1.5
			Evening	8.2	1104	694	483	ND	483	398	192	106	205	4.9	89	84	66	1.2
		Post Monsoon	Morning	7.3	966	589	230	ND	230	355	66	16	146	1.3	59	48	46	1.1
			Evening	7.7	778	477	280	ND	280	235	120	25	146	1.2	63	53	48	0.9
		Winter	Morning	7.6	1080	668	319	ND	319	417	98	48	171	3.1	65	61	55	1.4
			Evening	8.0	893	557	356	ND	356	295	148	48	172	2.9	70	67	58	1.1
		Spring	Morning	7.8	1166	718	393	ND	393	470	127	78	186	3.9	74	66	56	1.7
			Evening	8.2	982	608	421	ND	421	348	170	78	187	3.6	80	73	59	1.5
	2012-13	Pre Monsoon	Morning	7.8	1312	831	532	ND	532	553	162	113	237	6.7	89	77	72	1.6
			Evening	8.3	1125	719	588	4	584	431	218	112	236	6.6	90	78	74	1.4
		Post Monsoon	Morning	7.4	970	621	299	ND	299	389	71	27	181	2.5	69	51	54	1.4
			Evening	7.9	783	507	390	ND	390	268	155	36	180	2.3	69	51	56	1.1
		Winter	Morning	7.6	1067	699	401	ND	401	451	116	57	203	4.9	76	59	57	2.0
			Evening	8.1	881	587	449	ND	449	328	176	52	202	4.8	78	60	60	1.6
		Spring	Morning	7.8	1162	749	443	ND	443	499	131	80	219	6.1	86	72	63	2.5
			Evening	8.3	975	635	501	ND	501	378	198	80	218	6.2	88	75	66	2.0
	2013-14	Pre Monsoon	Morning	7.9	1266	789	551	ND	551	557	169	118	247	7.2	92	86	74	1.9
			Evening	8.4	1081	676	562	ND	562	435	216	119	231	7.0	92	86	77	1.5
		Post Monsoon	Morning	7.5	929	570	340	ND	340	399	85	42	185	1.6	66	49	55	1.5
			Evening	8.0	742	455	390	ND	390	278	155	52	173	1.7	67	51	57	1.0
		Winter	Morning	7.7	1029	647	422	ND	422	461	125	75	205	4.2	73	70	61	2.0
			Evening	8.2	842	534	452	ND	452	339	175	78	199	4.0	78	72	63	1.4
		Spring	Morning	7.8	1108	702	480	ND	480	514	142	92	226	6.0	82	74	69	2.4
			Evening	8.3	923	590	530	9	521	390	201	89	226	5.9	88	79	71	1.9

Note: All Values Except pH & EC are in mg/L.

Table: 21

Heavy Metals Concentration and Some Physicochemical Analysis of Ladpura Tehsil

S. No.	Name of Location	Year	Parameters			Trace Heavy Metal						Data Interpretation					
			DO	BOD	COD	Fe	Cd	Cu	Zn	Mn	Pb	AI	LSI	%Na	SAR	RSC	ESP
1	Rangpur (GWS)	2011-12	6.7	3.5	2.5	0.08	ND	0.02	ND	0.02	0.02	12.90	0.29	48.19	3.61	-3.08	3.90
		2012-13	6.1	3.8	2.8	0.07	ND	0.03	ND	0.01	0.06	13.23	0.59	50.47	4.14	-1.91	4.62
		2013-14	5.2	3.9	2.9	0.09	ND	0.01	ND	0.03	0.05	13.26	0.62	51.56	4.33	-1.74	4.88
2	Girdharpura (GWS)	2011-12	5.8	4.1	3.1	0.06	ND	ND	0.13	ND	0.02	12.94	0.29	44.69	3.38	-3.00	3.60
		2012-13	5.9	4.2	3.2	0.08	ND	ND	0.14	ND	0.03	13.24	0.57	47.10	3.87	-1.83	4.26
		2013-14	6.1	4.8	3..3	0.09	ND	ND	0.11	ND	0.04	13.31	0.64	48.10	4.03	-1.75	4.47
3	Alaniya (GWS)	2011-12	6.2	2.6	5.8	0.11	ND	ND	ND	0.01	ND	12.83	0.15	41.12	3.11	-2.79	3.22
		2012-13	6.3	2.1	5.7	0.12	ND	ND	ND	0.05	ND	13.09	0.39	43.75	3.58	-1.57	3.87
		2013-14	6.1	2.8	5.9	0.13	ND	ND	ND	0.03	ND	13.19	0.49	44.68	3.71	-1.62	4.04
4	Kasar (GWS)	2011-12	5.9	3.2	4.3	0.04	ND	ND	0.18	ND	0.01	12.89	0.16	37.85	2.80	-2.66	2.78
		2012-13	5.3	3.3	4.2	0.06	ND	ND	0.17	ND	0.02	13.16	0.42	40.78	3.29	-1.30	3.47
		2013-14	5.5	3.7	4.8	0.02	ND	ND	0.15	ND	0.03	13.21	0.48	41.83	3.44	-1.42	3.67
5	Kalyakheri (GWS)	2011-12	5.4	2.2	3.5	0.18	ND	0.05	ND	0.08	ND	12.87	0.10	36.14	2.62	-2.28	2.54
		2012-13	6.3	2.1	3.6	0.17	ND	0.04	ND	0.09	ND	13.15	0.38	39.23	3.12	-0.90	3.24
		2013-14	6.2	2.5	3.8	0.19	ND	0.02	ND	0.07	ND	13.18	0.42	40.37	3.27	-1.09	3.44
6	Jakhora (GWS)	2011-12	6.3	2.8	4.2	0.12	ND	ND	0.03	ND	0.12	12.73	-0.10	36.07	2.49	-2.44	2.35
		2012-13	6.1	2.9	3.8	0.11	ND	ND	0.04	ND	0.13	13.08	0.24	39.42	3.00	-1.04	3.07
		2013-14	5.2	3.1	3.7	0.14	ND	ND	0.06	ND	0.15	13.11	0.29	40.23	3.12	-1.20	3.23

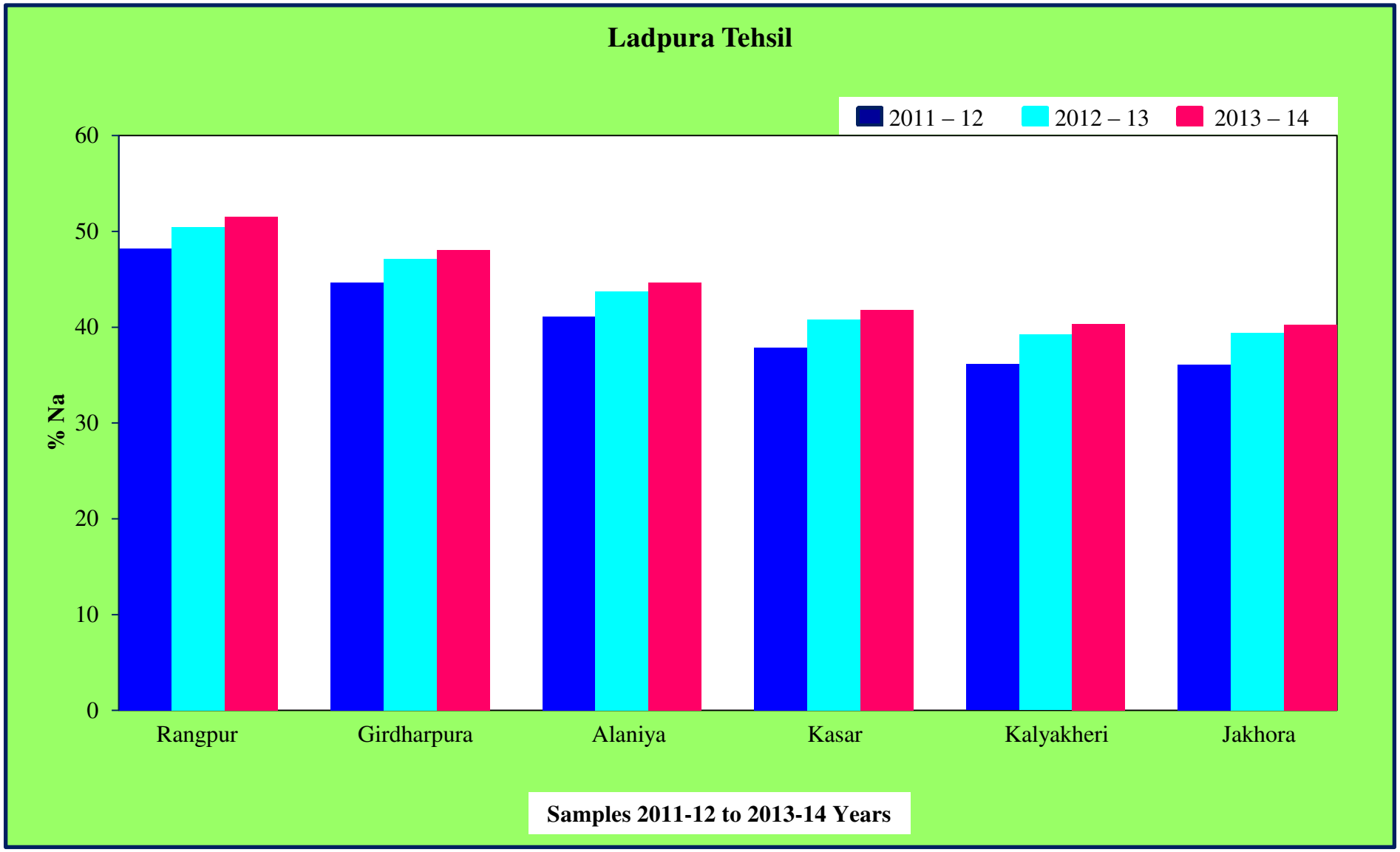

Fig 3A: Comparative Study of %Na in Ladpura Tehsil for Three Consecutive Years

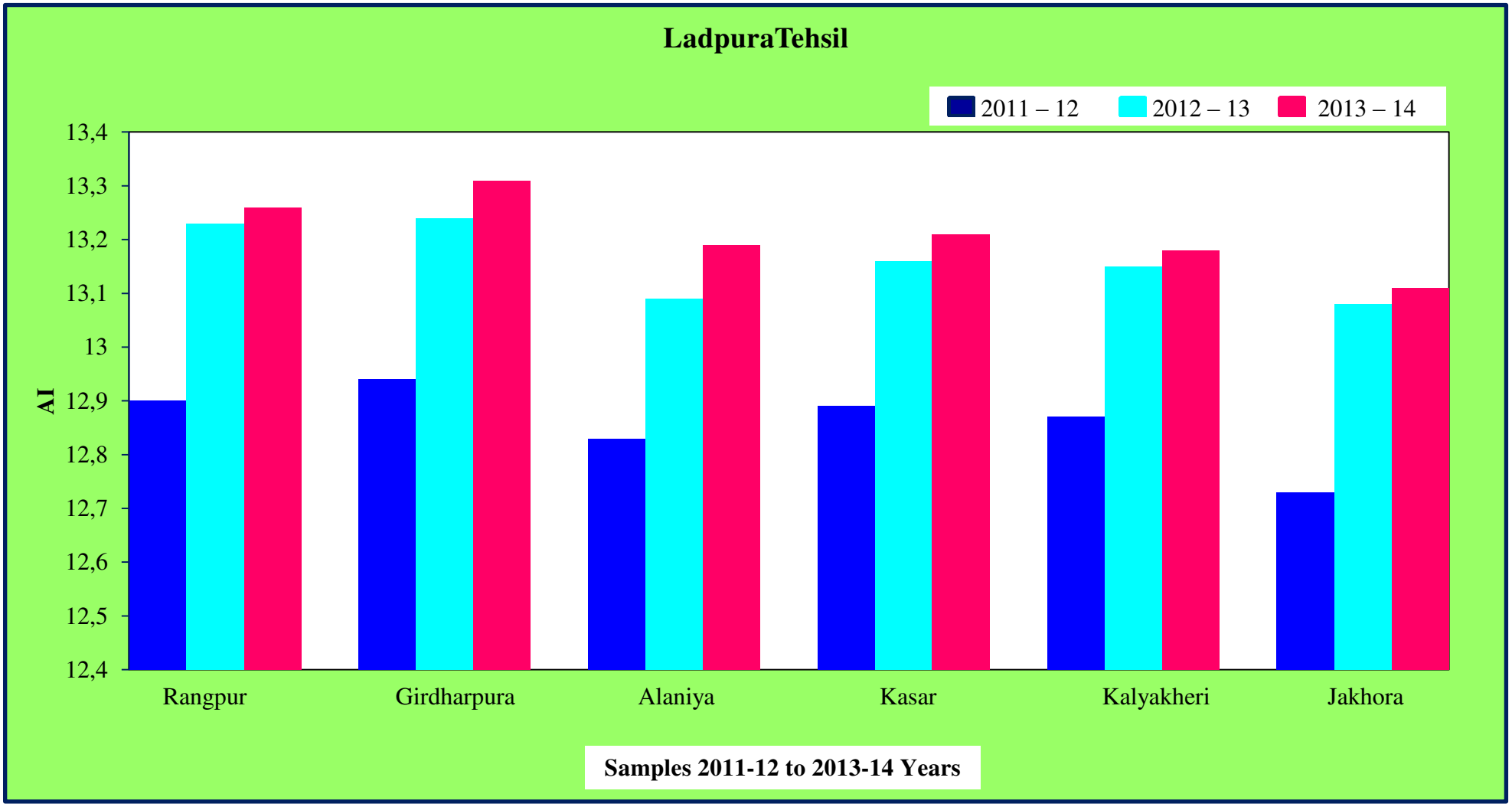

Fig 3B: Comparative Study of AI in Ladpura Tehsil for Three Years

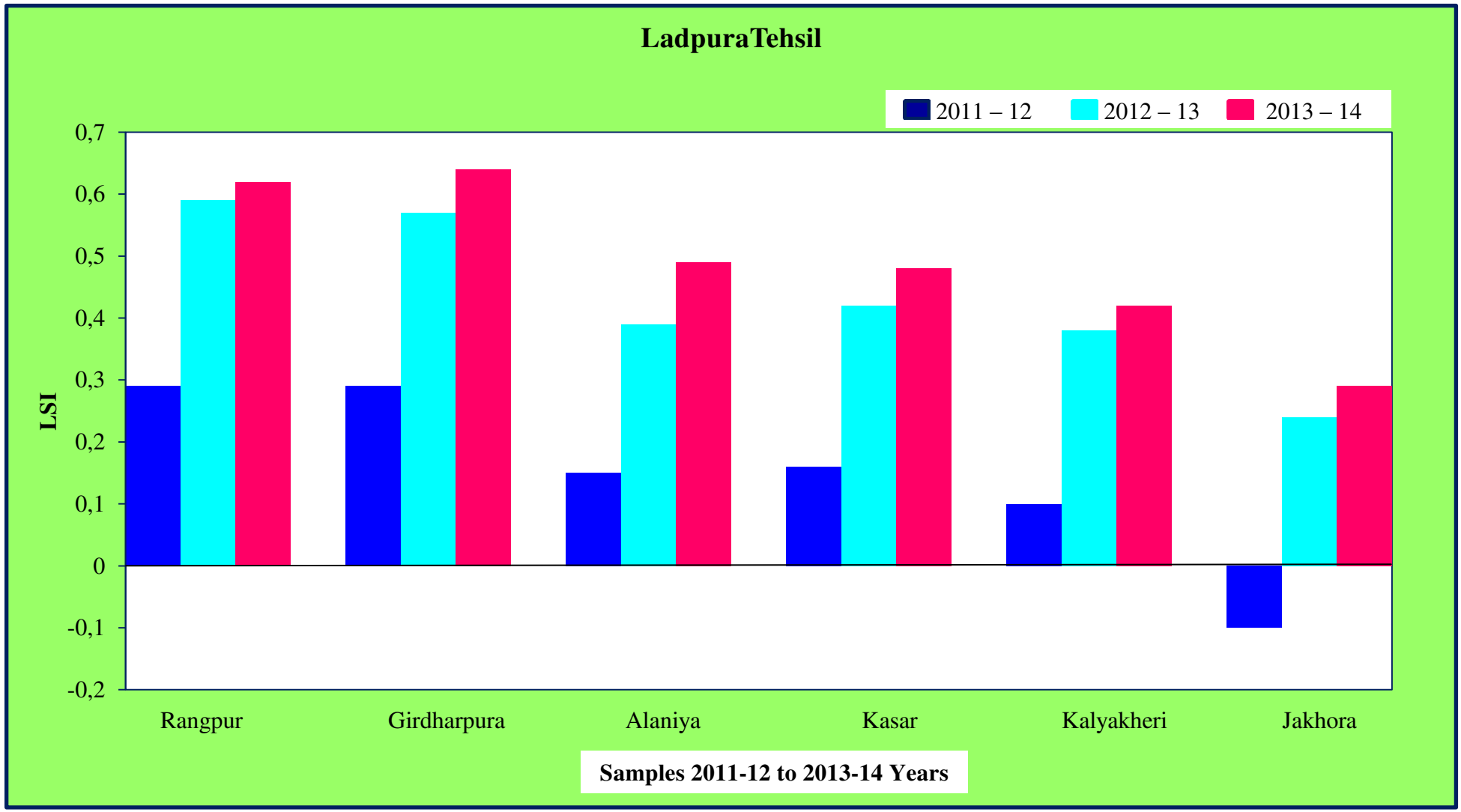

Fig 3C: Comparative Study of LSI in Ladpura Tehsil for Three Years

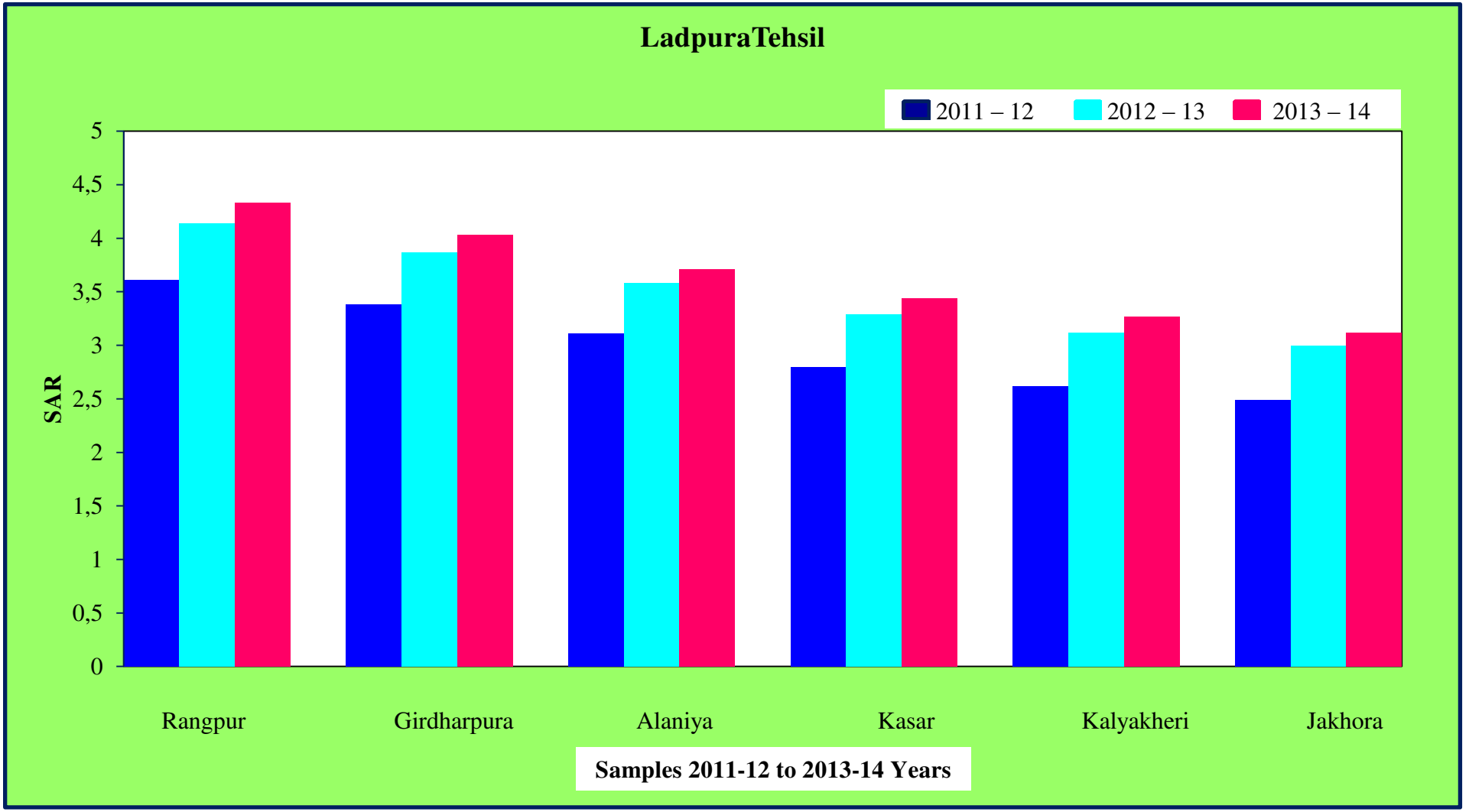

Fig 3D: Comparative Study of SAR in Ladpura Tehsil for Three Years

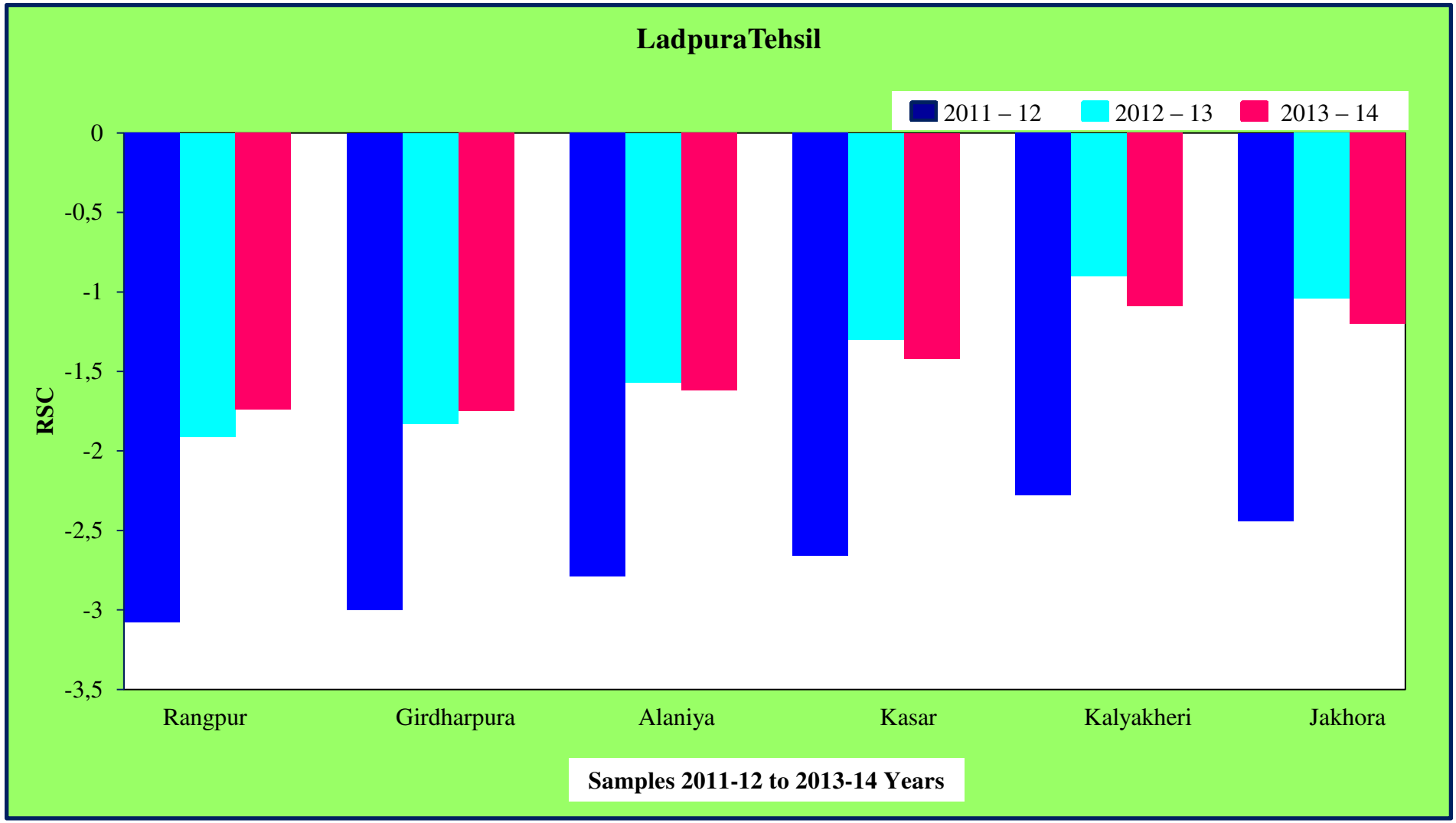

Fig 3E: Comparative Study of RSC in Ladpura Tehsil for Three Years

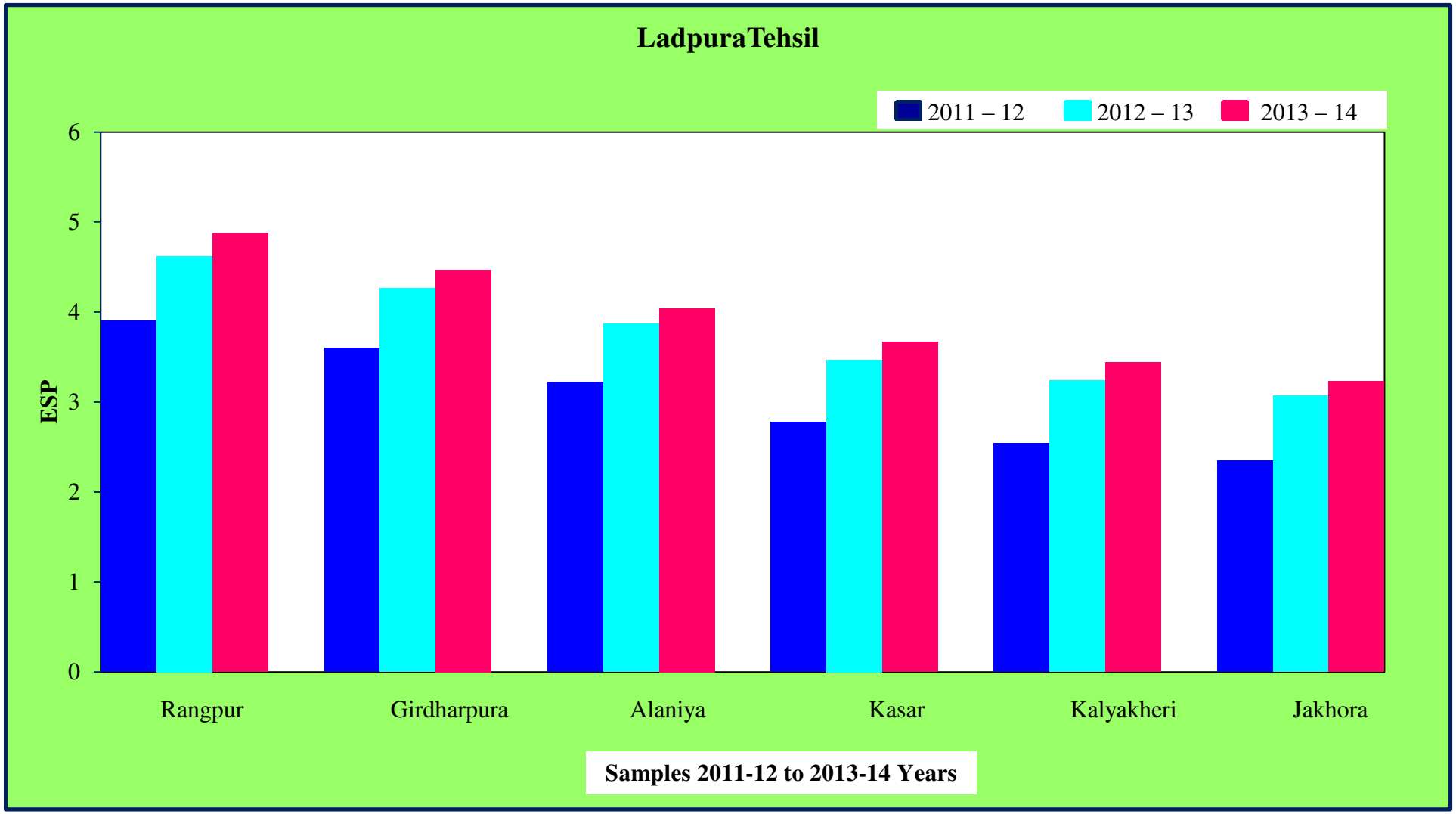

Fig 3F: Comparative Study of ESP in Ladpura Tehsil for Three Years

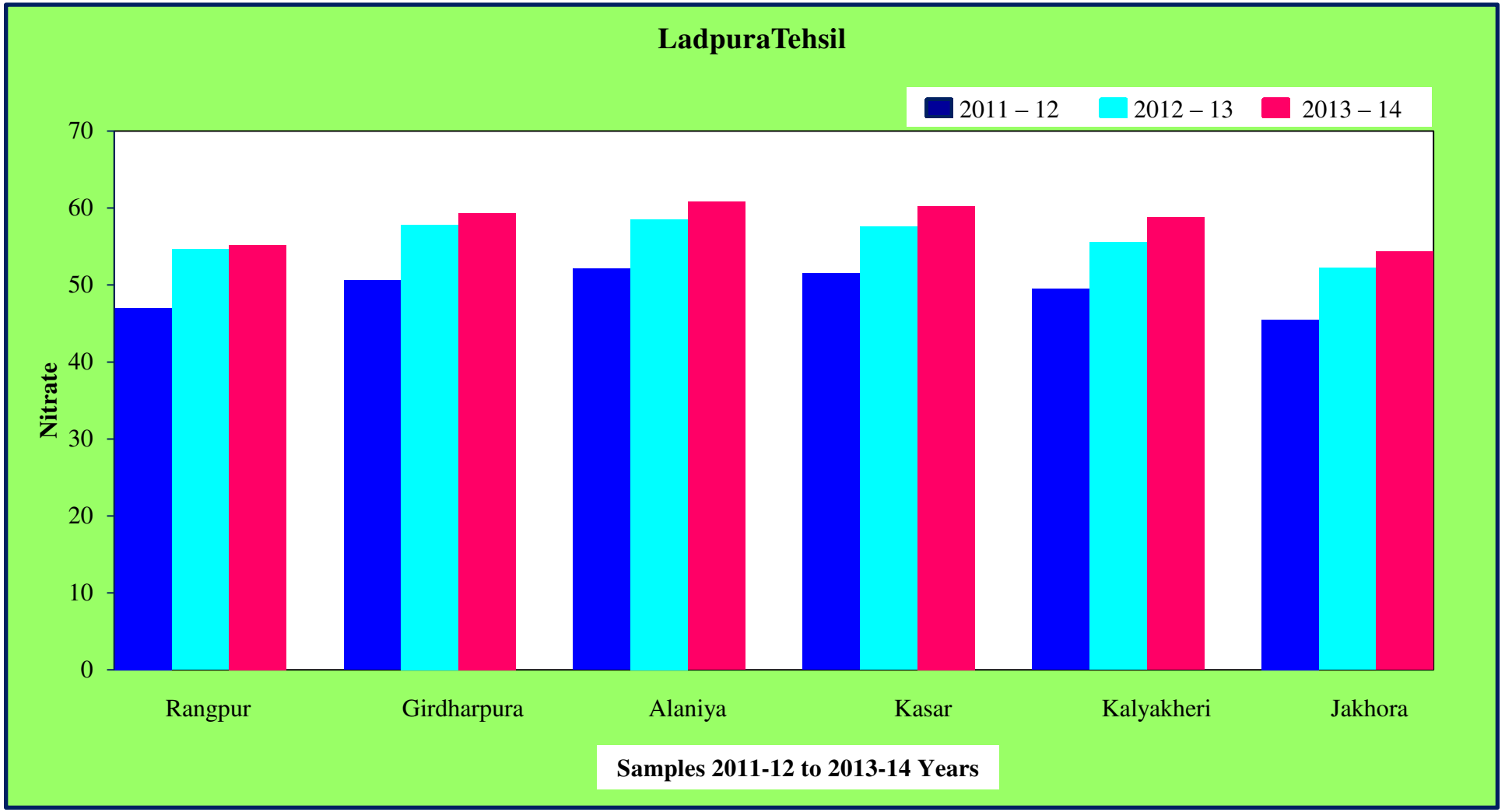

Fig 3G: Comparative Study of Nitrate in Ladpura Tehsil for Three Years

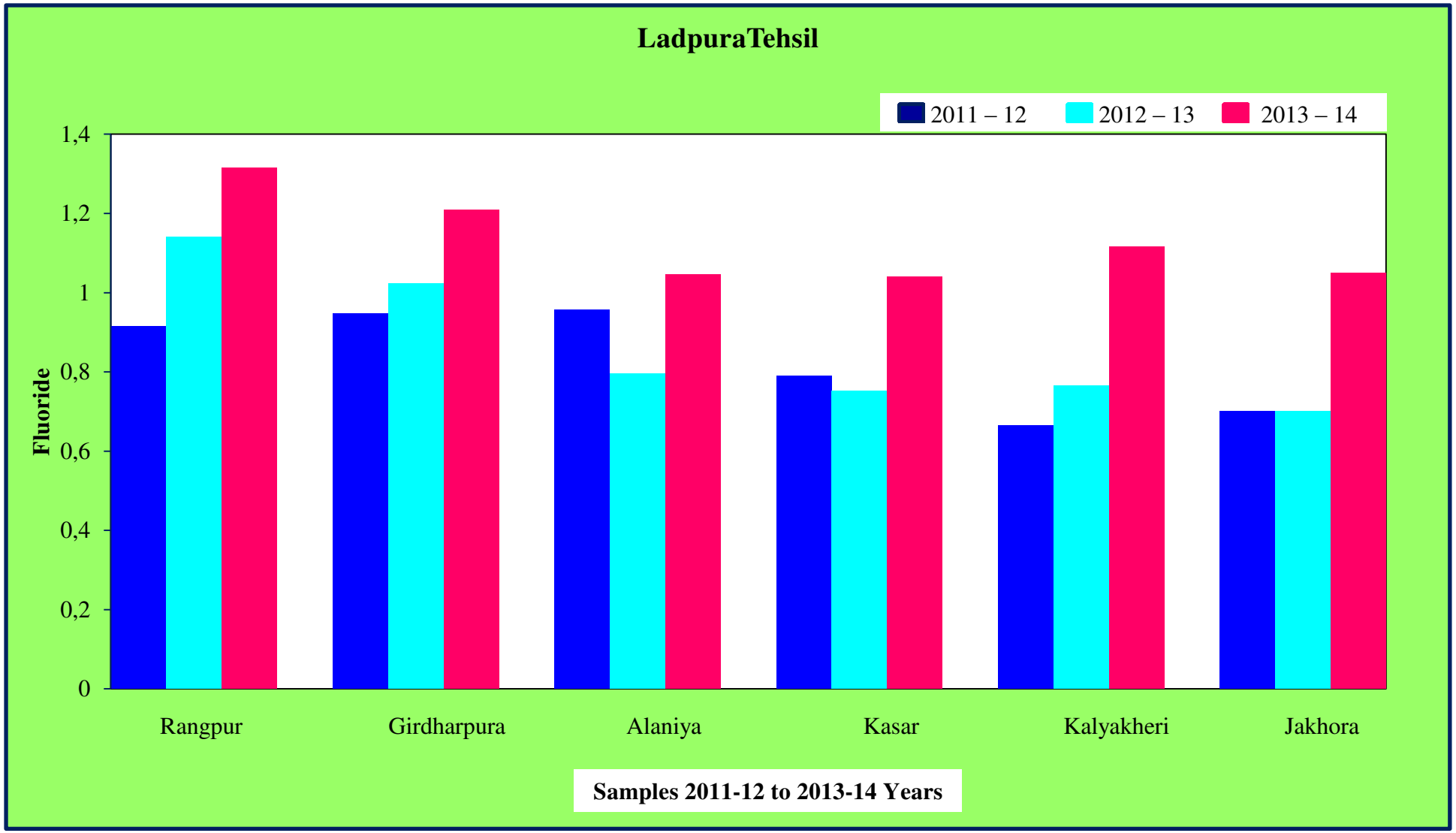

Fig 3H: Comparative Study of Fluoride in Ladpura Tehsil for Three Years

RAMGANJMANDI TEHSIL

The quantitative analysis of physicochemical parameters of six village of each tehsil of Kota district for the three years (from April, 2011 to March 2014) during four seasons (pre-monsoon, post-monsoon winter and spring) in morning and evening time period are shown in Table no - 22 to 27, analysis of heavy metals and of some others physicochemical parameters are presented in Table No – 28 and comparative studies are represented by Fig No – 4A to 4H.

WATER QUALITY PARAMETERS

pH Values

The pH values of groundwater samples were ranged from 7.1 (GWS/R/3-2011-12/post-monsoon), (GWS/R/11-2011-12/post-monsoon) to 8.3 (GWS/R/9-2013-14/Pre-monsoon) with overall average value 7.7 in successive three years analysis, all samples have within the permissible limit. The permissible limit of pH values for drinking water is specified as 6.5 to 8.5 as per IS 10500.

Conductance

In pre-monsoon period when water gets concentrated the conductance goes on higher side. The values of conductance of groundwater samples are ranged from 515 (GWS/R/5-2013-14/pre-monsoon) to 1670 µS (GWS/R/11-2013-14/pre-monsoon) with overall average value 997.2µS of successive three years analysis. The ionic concentration of groundwater is showing large dependence on water percolation.

Total Dissolved Solids

Normally ground water has a higher total dissolved solids load compared to surface water. The TDS of groundwater samples ranged from 399 (GWS/R/6-2013-14/post-monsoon) to 1296 (GWS/R/4-2012-13/pre-monsoon) mg/L with an average value of 679.2 mg/L. High TDS values observed in pre—monsoon season due to water concentrated. Lower values in post –monsoon was found due dilution of water with rainwater.

Total Alkalinity

According to IS 10500 the maximum allowable concentration of total alkalinity for drinking water is 600 mg/L. Total alkalinity of groundwater samples varies from 206 (GWS/R/5-2013-14/post-monsoon) mg/L to 668 (GWS/R/11-2013-14/Pre-monsoon) mg/L with overall average of 397.4 mg/L of successive three years analysis. Only 03 samples have higher values than the permissible limit of drinking water standard IS 10500.

Carbonate Alkalinity

In maximum number of analyzed samples carbonates alkalinity ND (Non detectable) and only in 5 samples carbonates alkalinity was detected. The values varied between 2 to 6 mg/L. The minimum value was observed in GWS/R/6-2013-14/Winter, GWS/R/12-2012-14/post-monsoon and maximum in GWS/R/4-2012-13/Winter.

Bicarbonates Alkalinity

Bicarbonates alkalinity ranged from 206 to 668 mg/L with an overall average of 397.2 mg/L in analyzed samples during successive three years. In sample GWS/R/5-2013-14/post-monsoon minimum value of bicarbonates alkalinity was observed and in sample GWS/R/12-2013-14/pre-monsoon maximum value of bicarbonates alkalinity was observed.

Total hardness

Hardness is the property of water, which prevents the lather formation with soap and increase the boiling point of water. The total hardness of groundwater samples ranged from 155 (GWS/R/1-2011-12/post-monsoon) to 628 (GWS/R/12-2012-13/pre-monsoon) mg/L with overall average of 406.7 mg/L of successive three years analysis.

Calcium Hardness

Calcium is one of most abundant elements found in natural water. The calcium hardness of groundwater samples ranged from 138 to 463 mg/L with overall average of 252.5 mg/L of successive three years analysis.

Magnesium Hardness

Magnesium is one of the important cations imparting hardness to the waters. Magnesium is determined as the difference between the total hardness and calcium hardness. The magnesium hardness ranged from 41 to 292 mg/L with overall average of 152.9 mg/L of successive three years analysis.

Sodium

Sodium values ranged from 102 to 259 mg/L and the average values of sodium was 177.1 mg/L in all of the studied samples of successive three years. The maximum value of sodium examined in sample GWS/R/12-2011-12/post-monsoon and the minimum value of sodium measured in sample GWS/R/5-2012-13/pre-monsoon and 2013-14/ pre-monsoon.

Potassium

Potassium values ranged from 0.9 to 20.1 mg/L and the average value of potassium was 7.7 mg/L in all of the studied samples of successive three-years. The maximum value of potassium examined in sample GWS/R/3-2013-14/pre-monsoon.

Chloride

Chloride occurs naturally in all types of waters. In natural fresh waters, its concentration remains quite low. The chloride concentration in groundwater samples varies from 79 to 318 mg/L with overall average of 149 mg/l of successive three years analysis. The values observed are within the specified limit of 250 mg/L as per IS 10500.

Sulphate

sulphate is an important anion imparting hardness to the waters. The sulphate ion produces cathartic effect upon human beings when it is presents in excess. The sulphate ion concentration in groundwater samples ranged from 84 to 296 mg/L with overall average of 153.8 mg/L of successive three years analysis. The maximum allowable limit of sulphates in drinking water as per IS 10500 is 400 mg/L.

Nitrate

Nitrate is one of the critical nutrients for the growth of algae and helps accelerating the eutrophication Nitrate content in groundwater samples varies from 10 to 83 mg/L with overall average of 39.8 mg/L of successive three years analysis. One third samples were having higher values than the permissible limit. The maximum allowable limit of nitrate in drinking water as per IS 10500 is 45 mg/L.

Fluoride

The fluoride ion concentrations in the study were within the specified limit and ranged from 0.2 to 2.5 mg/L with overall average of 1.0 mg/L in successive three years analysis. As per IS 10500 maximum fluoride concentration in drinking water is 1.50 mg/L.

Dissolved Oxygen

The data table reveals that DO values were ranged from 4.1 to 7.9 mg/L for the entire ground water samples and no major variations found in these values. The minimum value of DO was observed in sample GWS/Barodiyakalan/2011-12 and maximum value in sample GWS/Gundi/2012-13.

Biological Oxygen Demand

Values ranged from 1.1 to 3.9 mg/L for the entire ground water samples. BOD was monitored in sample GWS/Julmi/2011-12 as minimum value and BOD was monitored in samples GWS/Satalkheri/2011-12 as maximum values.

Chemical Oxygen Demand

Values were varied from 2.1 to 8.3 mg/L in the entire ground water samples. A maximum value of 6.4 mg/L was monitored in sample GWS/Barodiyakalan/2013-14.

Heavy Metals

Heavy metal is like Fe, Cd, Cu, Zn, Mn, and Pb were analyzed during for successive three years. Heavy metals like Cd, Cu, Mn and Zn were ND and those samples have some values of these metals were under permissible limits of IS 10500 and WHO. Fe values ranged from 0.01 to 0.31 mg/L. These values were within the prescribed limit. Pb was also ND at maximum sites except GWS/ Barodiyakalan, GWS/ Satalkheri, GWS/ Julmi and GWS/ Goyanda where values ranged from 0.02 to 0.37 mg/L and these all values were under permissible limits of IS 10500 and WHO the recommended standards.

CALCULATED INDICES

Aggressive Index (AI): Calculated values of aggressive index for all the samples analyzed in successive three years was ranged from 12.65 to 13.18 with an overall average of 12.91.

Langelier Saturation Index (LSI)

A calculated value of Langelier saturation index (LSI) was varied from -0.02 to 0.49 with an overall average of 0.222 for all the samples analyzed in successive three years. Use of groundwater without any treatment may result in such manner; all samples result in mild scale/ encrustation. Data reveals that nature of groundwater samples of study area were neither severe corrosive nor severe scale/encrustation but usually mild conditioning is required.

Percentage Sodium (% Na)

Calculated values of percentage sodium (%Na) were ranged from 38.93 to 60.08 with overall average of 49.29 for all the samples analyzed in successive three years. The minimum value was found in sample (GWS/Goyanda) during 2011-12. Use of water having excess sodium percentage is not suitable not suitable for irrigational purpose. Data reveals that 15 samples were of good class, 3 samples were in permissible class.

Sodium Adsorption Ratio (SAR)

The calculated values of sodium adsorption ratio (SAR) were ranged from 2.99 to 5.25 with overall average of 4.14 for all the samples analyzed in successive three years. Classification of groundwater samples as per US agricultural norms reveals that all samples were of medium (S_2) class.

Residual Sodium Carbonate (RSC)

The calculated values of residual sodium carbonates (RSC) were ranged from -4.05 to 2.16 with overall average of -1.35 for all the samples analyzed in successive three years. Maximum value of RSC was calculated in sample GWS/BarodiyaKalan-2012-12 and minimum value was in sample GWS/Goyanda-2012-13.

Exchangeable Sodium Percentage (ESP)

The calculated values of exchangeable sodium percentage (ESP) were ranged from 3.06 to 6.09 with overall average of 4.61 for all the samples analyzed in successive three years. Maximum value of ESP was calculated in sample GWS/BarodiyaKalan-2013-14 and minimum value was in sample GWS/Goyanda-2011-12.

Table: 22

Physico-Chemical Parameters of Groundwater of Ramganjmandi Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Barodiya Kalan (GWS) R1-Morning R2-Evening	2011-12	Pre Monsoon	Morning	8.0	1098	634	406	ND	406	317	208	124	190	7.3	123	135	46	0.6
			Evening	8.0	1145	662	421	ND	421	355	205	150	200	7.2	132	148	51	0.5
		Post Monsoon	Morning	7.6	778	437	212	ND	212	155	161	41	130	2.8	99	109	31	0.3
			Evening	7.5	824	464	210	ND	210	204	138	67	140	2.6	109	116	36	0.3
		Winter	Morning	7.8	883	493	287	ND	287	214	167	72	158	4.6	104	122	39	0.5
			Evening	7.8	928	519	296	ND	296	263	164	98	165	4.5	114	131	44	0.6
		Spring	Morning	7.9	975	552	360	ND	360	265	188	115	169	5.2	111	124	39	0.8
			Evening	7.9	1018	577	352	ND	352	303	184	118	178	5.2	122	133	44	1.0
	2012-13	Pre Monsoon	Morning	8.1	1116	654	473	ND	473	339	231	108	220	8.7	124	133	54	0.7
			Evening	8.1	1164	682	484	ND	484	355	228	127	230	8.5	134	143	59	0.7
		Post Monsoon	Morning	7.7	798	453	307	ND	307	221	175	46	166	4.5	104	106	32	0.5
			Evening	7.6	845	481	316	ND	316	268	185	82	155	4.4	102	116	40	0.4
		Winter	Morning	7.9	901	515	380	ND	380	264	198	65	191	7.0	111	113	44	0.7
			Evening	7.8	948	543	368	ND	368	265	190	75	197	7.0	120	122	49	0.5
		Spring	Morning	8.0	982	577	445	ND	445	316	217	98	208	8.5	118	124	49	0.9
			Evening	8.0	1029	607	450	ND	450	333	214	119	215	8.6	128	134	54	0.8
	2013-14	Pre Monsoon	Morning	8.2	1071	613	471	ND	471	332	227	105	232	9.0	129	143	57	0.9
			Evening	8.1	1121	640	456	ND	456	355	224	131	231	8.9	145	153	62	0.8
		Post Monsoon	Morning	7.7	741	411	313	ND	313	223	181	42	175	3.5	107	111	38	0.6
			Evening	7.7	791	438	307	ND	307	239	164	75	180	3.3	118	122	43	0.6
		Winter	Morning	7.9	846	468	366	ND	366	274	199	75	191	5.9	112	132	43	1.0
			Evening	7.9	898	497	361	ND	361	282	184	98	201	5.6	126	143	49	1.1
		Spring	Morning	8.0	941	535	429	ND	429	297	207	90	217	8.2	121	132	50	1.5
			Evening	8.0	993	564	436	ND	436	329	204	126	223	7.7	135	146	56	1.5

Note: All Values Except pH & EC are in mg/L.

Table: 23

Physico-Chemical Parameters of Groundwater of Ramganjmandi Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Gundi (GWS) R3-Morning R4-Evening	2011-12	Pre Monsoon	Morning	7.6	1238	1222	495	ND	495	586	321	264	184	18.2	213	160	60	0.8
			Evening	7.6	980	1273	392	ND	392	609	440	168	181	17.8	257	232	42	0.6
		Post Monsoon	Morning	7.1	775	1026	310	ND	310	317	175	142	124	13.9	112	99	45	0.2
			Evening	7.2	550	1076	220	ND	220	472	374	99	128	13.6	230	199	27	0.2
		Winter	Morning	7.3	1170	1084	468	ND	468	507	287	219	147	15.5	147	120	61	0.4
			Evening	7.4	655	1133	262	ND	262	503	398	105	145	15.0	235	211	35	0.5
		Spring	Morning	7.5	1203	1146	481	ND	481	578	318	260	179	16.3	201	168	62	0.8
			Evening	7.5	838	1194	335	ND	335	557	419	138	162	15.9	243	216	35	1.0
	2012-13	Pre Monsoon	Morning	7.7	775	1244	310	ND	310	620	355	265	214	19.6	318	287	69	1.0
			Evening	7.8	1253	1296	501	ND	501	628	463	165	210	19.0	242	220	50	0.7
		Post Monsoon	Morning	7.3	698	1042	279	ND	279	462	293	169	157	15.1	222	198	37	0.6
			Evening	7.3	758	1092	303	ND	303	442	356	87	154	14.4	195	186	35	0.4
		Winter	Morning	7.4	768	1105	307	ND	307	540	315	225	199	17.4	286	230	60	0.8
			Evening	7.5	945	1156	384	6	378	541	421	120	185	16.6	244	207	38	0.5
		Spring	Morning	7.5	785	1169	314	ND	314	617	358	259	205	18.7	311	276	63	1.2
			Evening	7.6	1113	1220	445	ND	445	609	452	156	198	17.8	253	219	44	0.8
	2013-14	Pre Monsoon	Morning	7.8	860	1200	344	ND	344	612	351	261	230	20.1	306	288	83	1.2
			Evening	7.9	1240	1253	496	ND	496	618	460	158	219	19.6	251	222	53	0.8
		Post Monsoon	Morning	7.3	678	999	271	ND	271	447	291	157	161	14.9	206	199	64	0.7
			Evening	7.5	780	1051	312	ND	312	480	381	99	176	14.5	239	201	33	0.4
		Winter	Morning	7.6	758	1057	303	ND	303	508	313	196	186	17.4	250	217	70	0.9
			Evening	7.7	1038	1110	415	ND	415	544	422	122	199	17.1	238	210	40	0.7
		Spring	Morning	7.7	830	1120	332	ND	332	570	336	234	226	19.8	287	279	77	1.2
			Evening	7.8	1080	1173	432	ND	432	583	446	137	207	19.7	269	204	47	0.9

Note: All Values Except pH & EC are in mg/L.

Table: 24

Physico-Chemical Parameters of Groundwater of Ramganjmandi Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Goyanda (GWS) R5-Morning R6-Evening	2011-12	Pre Monsoon	Morning	7.9	863	653	345	ND	345	501	256	246	225	5.3	241	267	48	1.5
			Evening	8.0	958	613	383	ND	383	487	219	269	216	5.5	204	251	41	1.7
		Post Monsoon	Morning	7.4	603	457	241	ND	241	381	194	187	181	1.2	199	220	33	1.2
			Evening	7.5	575	417	230	ND	230	358	154	204	157	1.3	180	190	27	1.3
		Winter	Morning	7.6	713	518	285	ND	285	412	210	202	211	2.7	224	232	41	1.3
			Evening	7.8	738	478	295	ND	295	399	175	224	181	2.9	186	204	34	1.5
		Spring	Morning	7.8	875	576	350	ND	350	497	250	246	222	3.2	236	259	41	1.4
			Evening	7.9	890	535	356	ND	356	443	196	247	198	3.5	196	209	35	1.7
	2012-13	Pre Monsoon	Morning	8.0	995	678	398	ND	398	525	281	244	259	6.8	261	275	56	1.6
			Evening	8.1	1158	638	463	ND	463	505	220	285	231	6.8	205	214	50	1.8
		Post Monsoon	Morning	7.6	775	469	310	ND	310	366	187	180	211	2.5	193	206	40	1.5
			Evening	7.7	880	429	352	ND	352	410	180	230	191	2.4	183	185	33	1.6
		Winter	Morning	7.8	905	526	362	ND	362	434	224	211	224	4.6	210	225	43	1.8
			Evening	7.9	995	488	398	ND	398	440	204	235	214	4.9	196	198	37	1.8
		Spring	Morning	7.9	885	586	354	ND	354	506	276	231	245	5.7	264	271	49	1.9
			Evening	8.0	1178	548	471	ND	471	503	227	277	228	6.2	204	206	43	2.0
	2013-14	Pre Monsoon	Morning	8.0	763	637	305	ND	305	482	265	218	259	7.9	282	296	58	1.9
			Evening	8.2	1190	596	476	ND	476	533	242	292	258	8.0	231	251	52	2.0
		Post Monsoon	Morning	7.6	515	438	206	ND	206	332	212	120	199	2.4	208	226	42	1.6
			Evening	7.7	845	399	338	ND	338	404	182	221	193	2.6	187	190	36	1.6
		Winter	Morning	7.8	628	502	251	ND	251	417	231	186	224	4.7	240	271	48	2.0
			Evening	8.0	958	464	385	2	383	442	202	241	217	4.7	200	214	42	2.1
		Spring	Morning	8.0	753	561	301	ND	301	477	259	219	251	7.4	275	289	56	2.3
			Evening	8.1	1185	522	474	ND	474	500	225	275	239	7.5	205	216	50	2.5

Note: All Values Except pH & EC are in mg/L.

Table: 25

Physico-Chemical Parameters of Groundwater of Ramganjmandi Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Satalkheri (GWS) R7-Morning R8-Evening	2011-12	Pre Monsoon	Morning	7.9	1165	692	466	ND	466	438	288	151	165	5.4	118	133	42	0.8
			Evening	7.7	1205	733	482	ND	482	477	349	128	164	5.5	125	140	46	1.1
		Post Monsoon	Morning	7.5	763	482	305	ND	305	323	224	98	104	1.2	88	97	26	0.5
			Evening	7.3	830	525	336	4	332	373	283	91	104	0.9	96	106	30	0.6
		Winter	Morning	7.7	940	554	376	ND	376	370	245	125	129	2.8	95	112	35	0.7
			Evening	7.5	1070	598	428	ND	428	428	313	116	137	2.6	103	120	39	0.9
		Spring	Morning	7.8	1115	613	446	ND	446	415	269	146	150	3.2	105	118	35	1.1
			Evening	7.6	1175	656	470	ND	470	460	345	116	151	2.9	113	125	40	1.2
	2012-13	Pre Monsoon	Morning	8.0	1333	715	533	ND	533	438	314	124	196	6.9	119	128	50	1.0
			Evening	7.9	1350	757	540	ND	540	467	376	91	197	7.1	126	135	54	1.2
		Post Monsoon	Morning	7.6	933	508	373	ND	373	326	250	76	141	2.2	95	98	33	0.7
			Evening	7.5	880	551	352	ND	352	325	279	46	140	2.3	100	107	37	1.0
		Winter	Morning	7.8	1140	581	456	ND	456	376	274	102	163	5.0	102	105	36	1.0
			Evening	7.7	1158	624	463	ND	463	401	332	68	169	5.2	113	114	40	1.2
		Spring	Morning	7.9	1288	645	515	ND	515	422	296	126	183	6.2	111	117	42	1.3
			Evening	7.8	1275	690	510	ND	510	448	354	95	181	6.6	121	128	46	1.4
	2013-14	Pre Monsoon	Morning	8.0	1353	669	541	ND	541	438	312	127	207	8.2	122	136	53	1.2
			Evening	7.9	1433	710	573	ND	573	493	373	120	206	8.5	130	144	57	1.3
		Post Monsoon	Morning	7.6	880	465	352	ND	352	309	250	59	146	2.9	99	107	34	0.6
			Evening	7.5	808	507	323	ND	323	300	240	61	144	3.3	106	110	38	0.8
		Winter	Morning	7.8	1065	536	426	ND	426	367	276	91	165	5.2	105	123	40	0.9
			Evening	7.7	1120	579	448	ND	448	414	335	79	164	5.4	113	131	44	0.9
		Spring	Morning	8.0	1290	596	516	ND	516	423	301	121	187	6.9	111	121	49	1.2
			Evening	7.9	1430	637	572	ND	572	480	365	115	197	7.2	119	130	51	1.1

Note: All Values Except pH & EC are in mg/L.

Table: 26

Physico-Chemical Parameters of Groundwater of Ramganjmandi Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Julmi (GWS) R9-Morning R10-Evening	2011-12	Pre Monsoon	Morning	8.1	1100	759	440	ND	440	452	240	212	166	11.7	144	157	28	0.7
			Evening	7.8	1170	780	468	ND	468	469	240	229	171	11.9	143	158	28	0.8
		Post Monsoon	Morning	7.7	575	553	230	ND	230	293	172	121	108	7.9	119	128	11	0.5
			Evening	7.3	645	573	258	ND	258	309	172	136	112	8.0	118	128	10	0.4
		Winter	Morning	7.9	783	627	313	ND	313	353	193	161	133	9.3	126	143	20	0.9
			Evening	7.6	870	648	348	ND	348	373	195	178	138	9.5	125	141	19	0.7
		Spring	Morning	8.0	1005	681	402	ND	402	431	225	206	149	10.1	137	149	20	1.4
			Evening	7.7	1133	702	453	ND	453	455	236	220	160	10.1	136	149	20	1.1
	2012-13	Pre Monsoon	Morning	8.3	1255	781	502	ND	502	450	266	183	197	13.4	145	154	37	0.8
			Evening	7.9	1333	803	533	ND	533	468	269	200	201	13.7	144	153	36	1.0
		Post Monsoon	Morning	7.9	798	581	319	ND	319	310	203	107	143	8.9	121	122	21	0.2
			Evening	7.5	870	604	348	ND	348	327	205	121	147	9.3	119	121	21	0.5
		Winter	Morning	8.1	1025	654	410	ND	410	381	236	145	163	11.3	131	132	25	0.7
			Evening	7.7	1035	678	414	ND	414	369	230	139	168	11.8	128	130	25	0.9
		Spring	Morning	8.2	1250	714	500	ND	500	439	260	180	188	12.8	135	142	31	1.3
			Evening	7.9	1280	737	512	ND	512	430	256	175	195	13.4	134	139	31	1.4
	2013-14	Pre Monsoon	Morning	8.3	1300	737	520	ND	520	449	265	184	206	14.9	140	162	40	0.9
			Evening	8.0	1353	758	546	5	541	468	267	201	211	15.0	146	161	39	1.2
		Post Monsoon	Morning	7.9	813	527	325	ND	325	321	201	120	144	9.1	123	127	20	0.6
			Evening	7.5	918	547	367	ND	367	325	204	121	148	9.1	107	121	19	0.8
		Winter	Morning	8.1	1003	601	401	ND	401	388	246	143	163	11.5	130	148	27	0.9
			Evening	7.7	1105	621	442	ND	442	421	242	179	173	11.5	136	151	26	1.2
		Spring	Morning	8.2	1310	654	524	ND	524	433	262	172	209	13.4	139	150	35	1.3
			Evening	7.8	1308	674	523	ND	523	456	260	197	201	13.4	140	156	34	1.7

Note: All Values Except pH & EC are in mg/L.

Table: 27

Physico-Chemical Parameters of Groundwater of Ramganjmandi Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Kheemach (GWS) R11-Morning R12-Evening	2011-12	Pre Monsoon	Morning	7.5	1383	793	553	ND	553	504	258	246	169	4.8	112	128	40	1.1
			Evening	7.8	1105	756	442	ND	442	392	202	189	160	5.0	106	121	36	1.2
		Post Monsoon	Morning	7.1	900	581	360	ND	360	336	183	152	120	1.1	85	95	24	0.8
			Evening	7.4	568	545	227	ND	227	224	139	85	102	1.2	79	88	21	0.8
		Winter	Morning	7.3	1070	658	428	ND	428	397	221	177	136	2.9	91	108	33	1.3
			Evening	7.6	783	621	313	ND	313	285	162	123	126	3.1	85	101	30	1.2
		Spring	Morning	7.5	1328	709	531	ND	531	491	251	240	152	3.3	105	113	34	1.8
			Evening	7.8	933	673	373	ND	373	331	186	145	143	3.5	95	108	31	1.6
	2012-13	Pre Monsoon	Morning	7.7	1650	821	660	ND	660	569	330	240	189	6.4	114	122	48	1.2
			Evening	8.0	1263	783	505	ND	505	392	227	165	190	6.5	107	115	45	1.4
		Post Monsoon	Morning	7.2	1160	608	464	ND	464	414	266	148	134	2.3	89	90	30	0.8
			Evening	7.5	845	569	340	2	338	267	162	105	135	2.2	81	84	27	0.9
		Winter	Morning	7.4	1360	679	544	ND	544	475	291	184	155	4.6	99	102	34	1.4
			Evening	7.7	1055	641	422	ND	422	332	186	146	156	4.3	91	96	31	1.4
		Spring	Morning	7.6	1510	725	604	ND	604	531	312	220	170	6.3	109	115	39	1.8
			Evening	7.9	1205	689	482	ND	482	377	220	157	177	6.1	101	108	36	1.9
	2013-14	Pre Monsoon	Morning	7.7	1670	772	668	ND	668	574	331	243	199	7.1	118	132	51	1.5
			Evening	8.0	1275	733	510	ND	510	394	226	168	199	7.4	110	126	48	1.5
		Post Monsoon	Morning	7.3	1158	560	463	ND	463	417	266	151	138	1.7	92	95	32	1.3
			Evening	7.6	803	521	321	ND	321	258	161	96	138	2.1	86	90	29	1.2
		Winter	Morning	7.5	1330	637	532	ND	532	478	292	186	158	4.4	100	118	38	1.5
			Evening	7.8	1020	598	408	ND	408	339	210	129	159	4.9	95	113	35	1.5
		Spring	Morning	7.8	1475	687	590	ND	590	521	315	206	179	6.1	112	124	46	1.9
			Evening	8.0	1200	649	480	ND	480	395	232	163	179	6.5	108	118	43	1.8

Note: All Values Except pH & EC are in mg/L.

Table: 28

Annual Heavy Metals Concentration and Some Physicochemical Analysis of Ramganjmandi Tehsil

S. No.	Name of Location	Year	Parameters			Annual Trace Heavy Metal						Data Interpretation					
			DO	BOD	COD	Fe	Cd	Cu	Zn	Mn	Pb	AI	LSI	%Na	SAR	RSC	ESP
1	Barodiya Kalan (GWS)	2011-12	4.1	2.2	8.1	0.11	ND	0.05	ND	0.03	0.21	12.69	0.08	56.48	4.36	0.86	4.92
		2012-13	4.6	2.1	8.2	0.14	ND	0.06	ND	0.01	0.17	12.97	0.35	58.66	5.01	2.16	5.77
		2013-14	5.1	2.7	8.3	0.12	ND	0.03	ND	0.05	ND	12.98	0.35	60.08	5.25	2.02	6.09
2	Gundi (GWS)	2011-12	7.8	3.5	3.1	0.21	ND	ND	0.01	ND	ND	12.70	0.00	48.51	3.77	-0.20	4.12
		2012-13	7.9	3.6	3.2	0.22	ND	ND	0.02	ND	ND	12.84	0.16	49.95	4.26	-1.58	4.77
		2013-14	7.1	3.7	3.3	0.23	ND	ND	0.03	ND	0.28	12.89	0.21	51.71	4.50	-1.33	5.09
3	Goyanda (GWS)	2011-12	6.2	2.2	2.5	0.28	ND	ND	ND	0.07	0.27	12.65	-0.02	38.93	2.99	-2.91	3.06
		2012-13	6.3	2.1	2.1	0.29	ND	ND	ND	0.06	0.21	12.80	0.14	41.68	3.50	-4.05	3.76
		2013-14	6.8	2.3	2.4	0.31	ND	ND	ND	0.04	0.31	12.92	0.26	43.37	3.73	-3.64	4.06
4	Satalkheri (GWS)	2011-12	5.1	3.9	5.1	0.02	ND	0.03	ND	ND	0.33	12.71	0.03	43.91	3.60	-3.75	3.88
		2012-13	5.2	3.8	5.3	0.03	ND	0.04	ND	ND	0.37	12.95	0.28	46.96	4.11	-2.50	4.57
		2013-14	5.5	3.6	5.4	0.02	ND	0.05	ND	ND	0.31	12.97	0.32	48.48	4.30	-3.04	4.83
5	Julmi (GWS)	2011-12	6.3	1.1	6.1	0.01	ND	ND	0.08	ND	0.02	12.86	0.07	49.65	4.14	-2.48	4.63
		2012-13	6.7	1.2	6.3	0.05	ND	ND	0.09	ND	0.05	13.12	0.34	51.25	4.57	-1.45	5.19
		2013-14	6.6	1.8	6.2	0.06	ND	ND	0.07	ND	0.04	13.08	0.33	52.43	4.73	-2.13	5.40
6	Kheemach (GWS)	2011-12	6.1	3.6	4.3	0.25	ND	ND	0.11	0.02	ND	12.89	0.17	46.03	3.50	-0.94	3.74
		2012-13	6.2	2.7	4.2	0.27	ND	ND	0.12	0.03	ND	13.15	0.45	49.14	4.05	0.35	4.50
		2013-14	6.8	3.2	4.1	0.22	ND	ND	0.13	0.04	ND	13.18	0.49	50.15	4.22	0.22	4.73

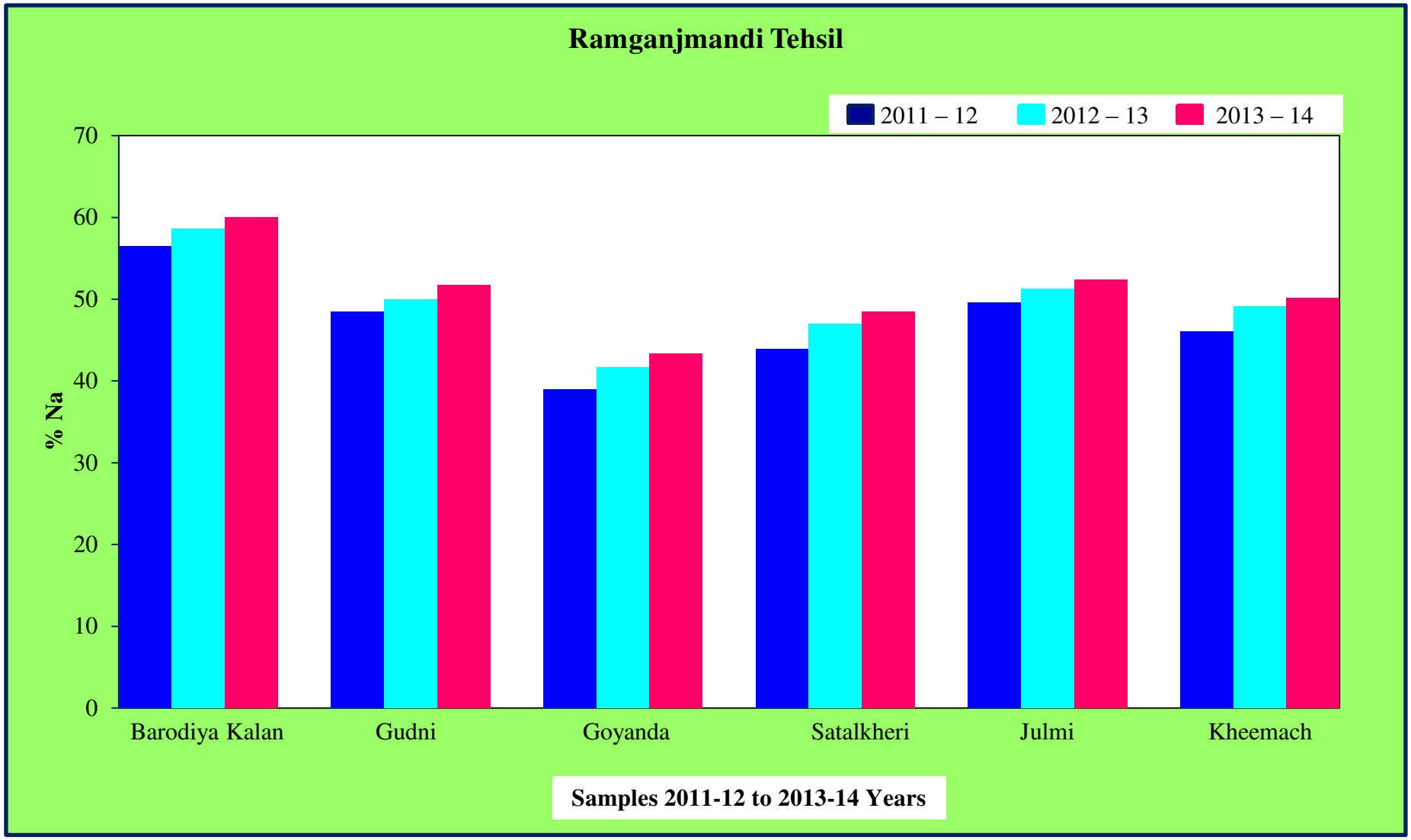

Fig 4A: Comparative Study of %Na in Ramganjmandi Tehsil for Three Years

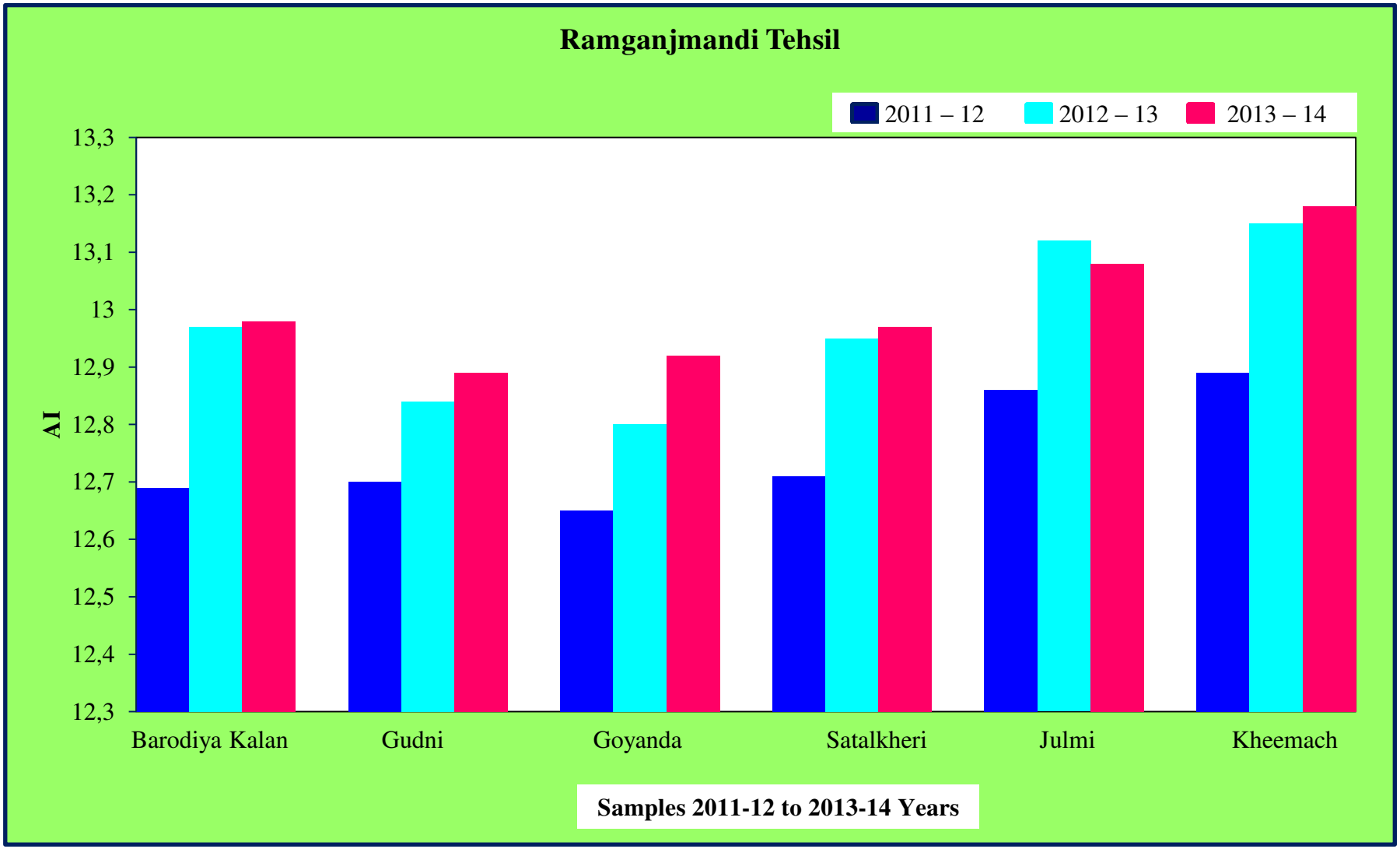

Fig 4B: Comparative Study of AI in Ramganjmandi Tehsil for Three Years

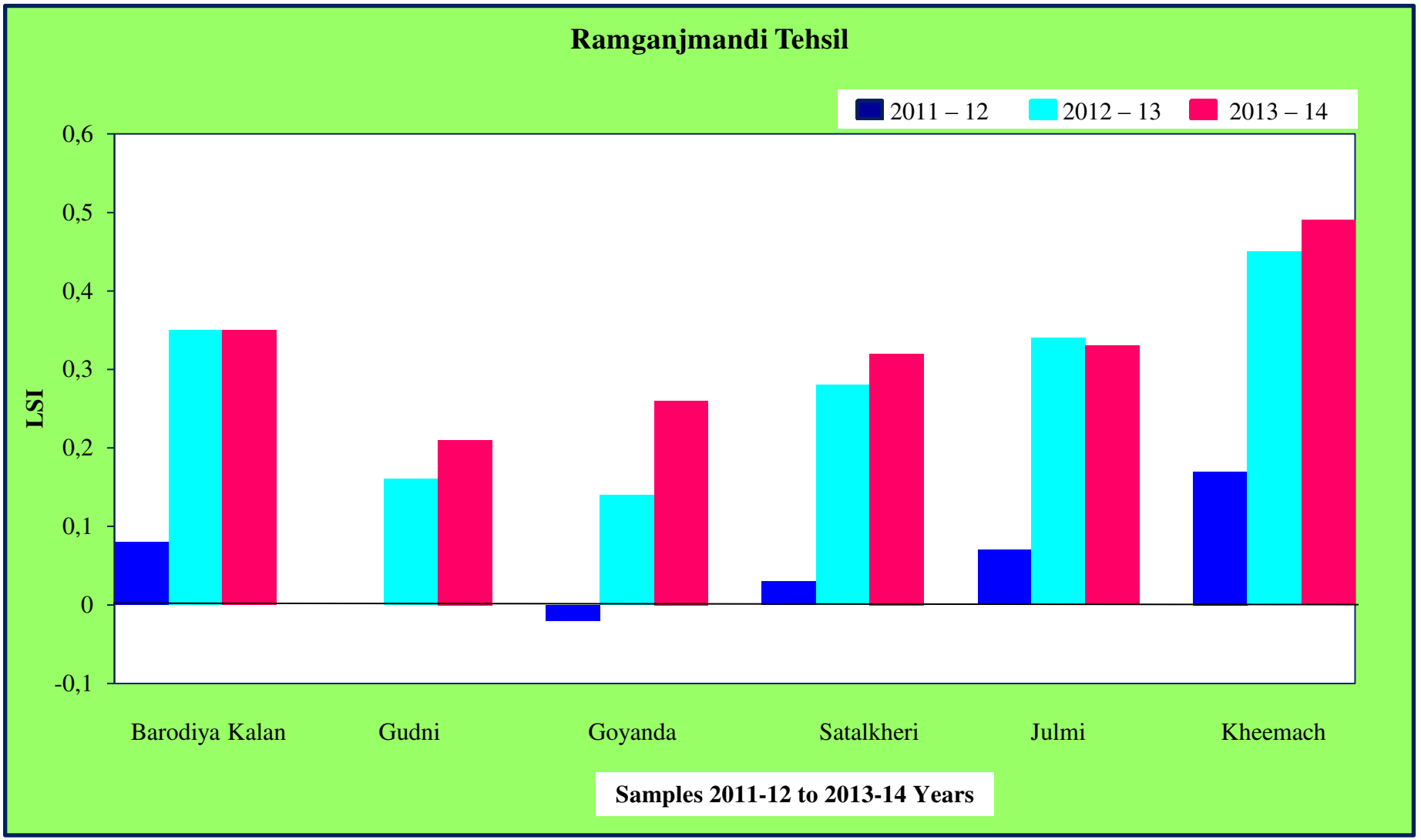

Fig 4C: Comparative Study of LSI in Ramganjmandi Tehsil for Three Years

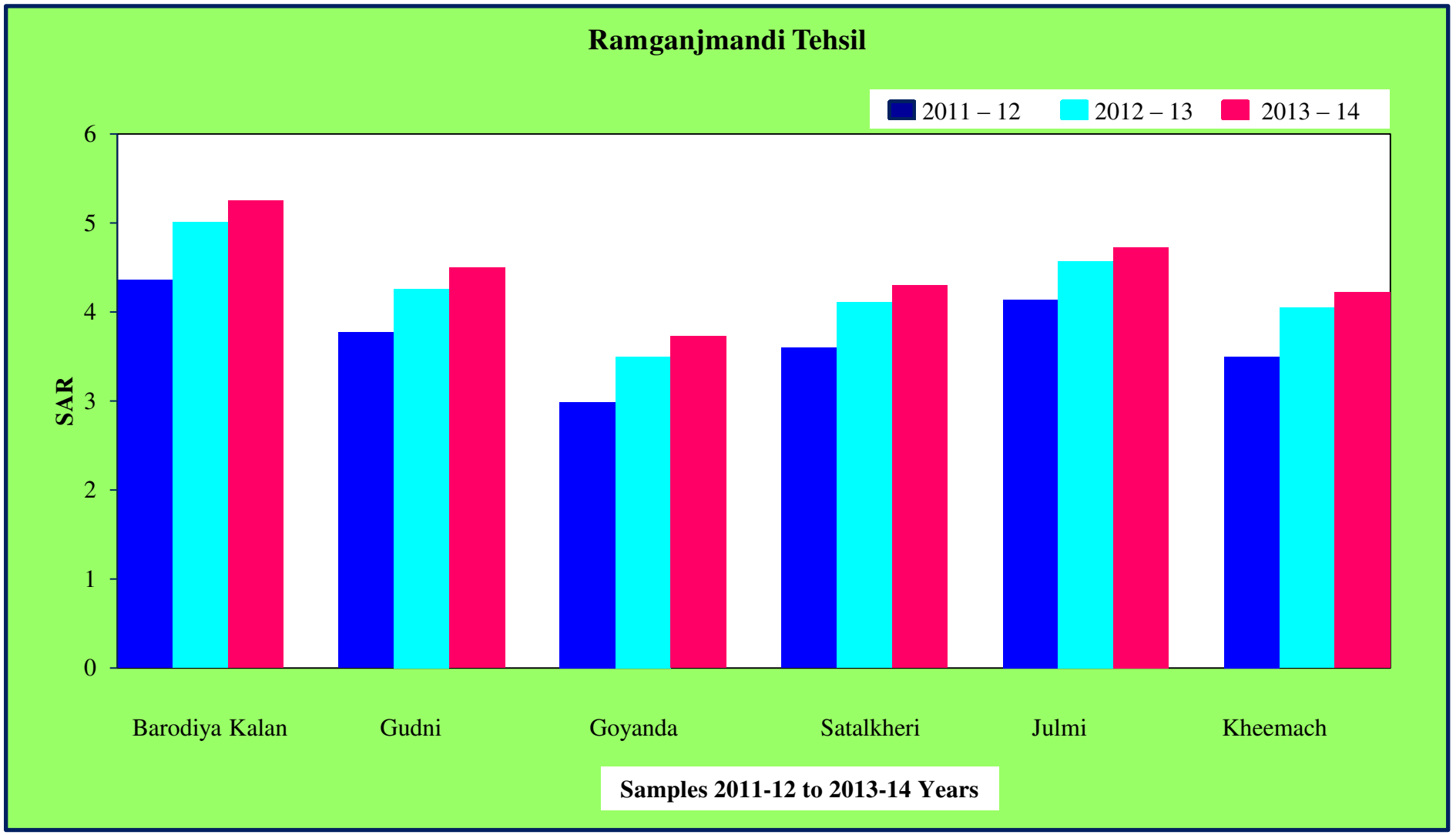

Fig 4D: Comparative Study of SAR in Ramganjmandi Tehsil for Three Years

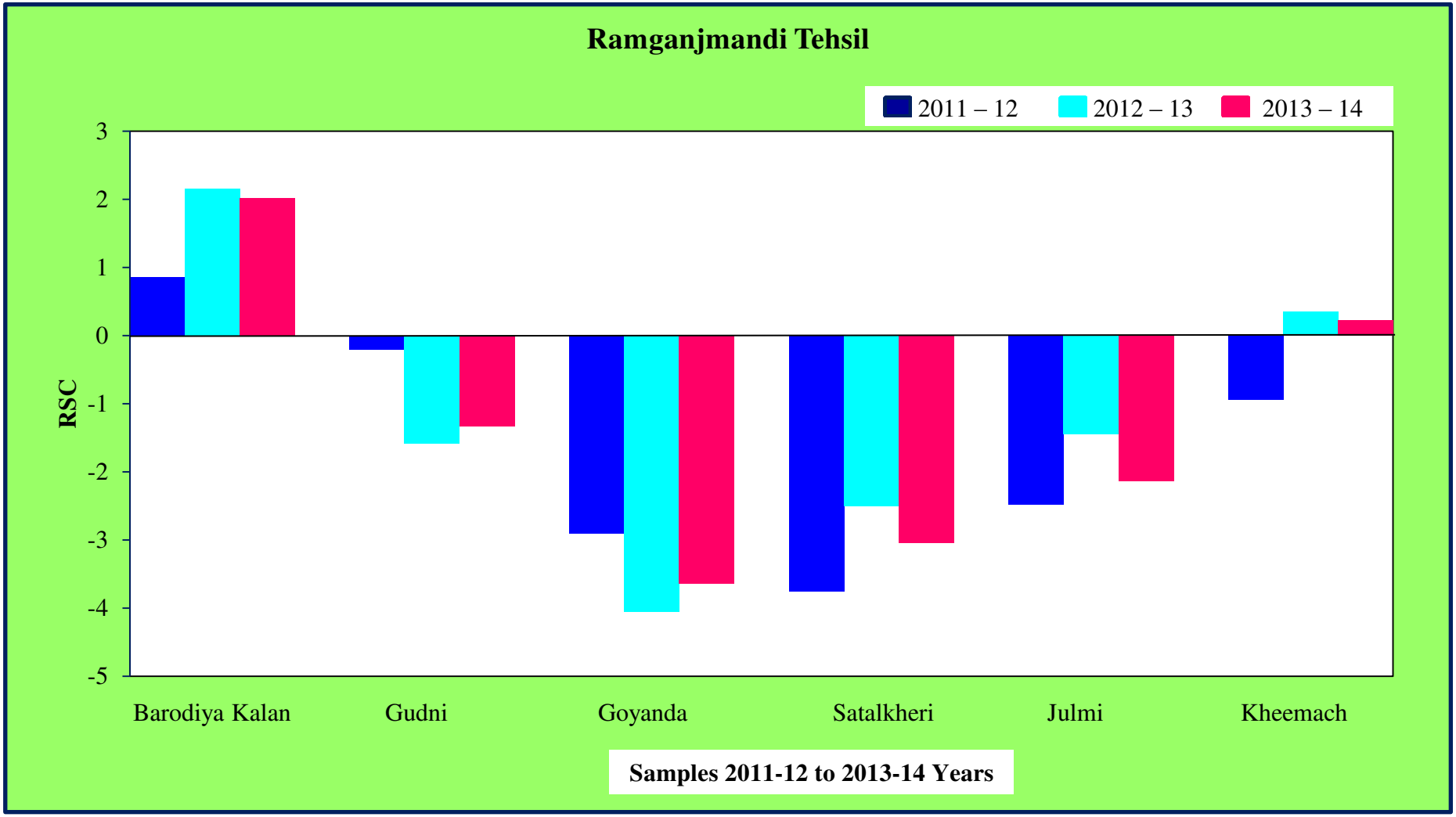

Fig 4E: Comparative Study of RSC in Ramganjmandi Tehsil for Three Years

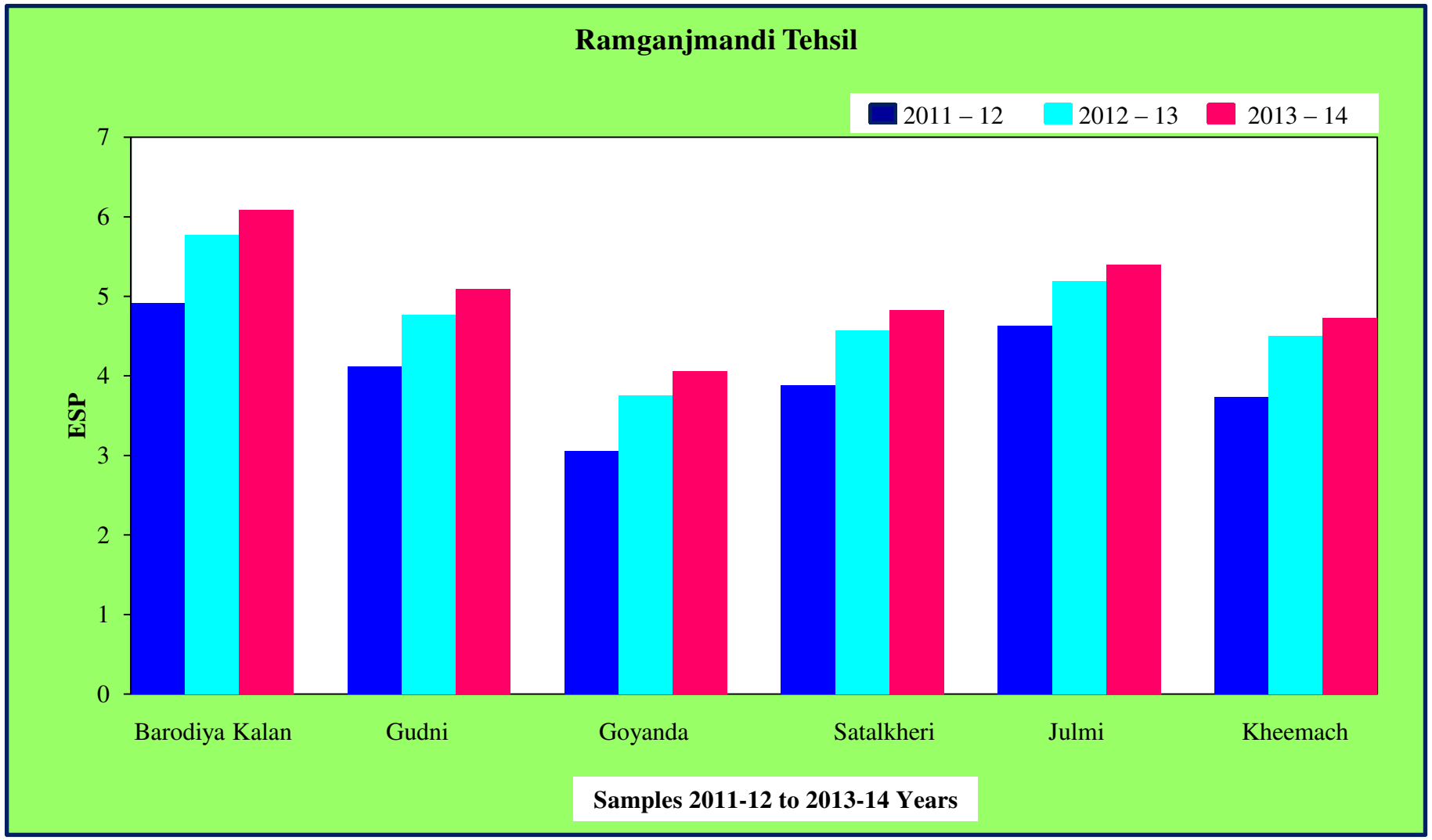

Fig 4F: Comparative Study of ESP in Ramganjmandi Tehsil for Three Years

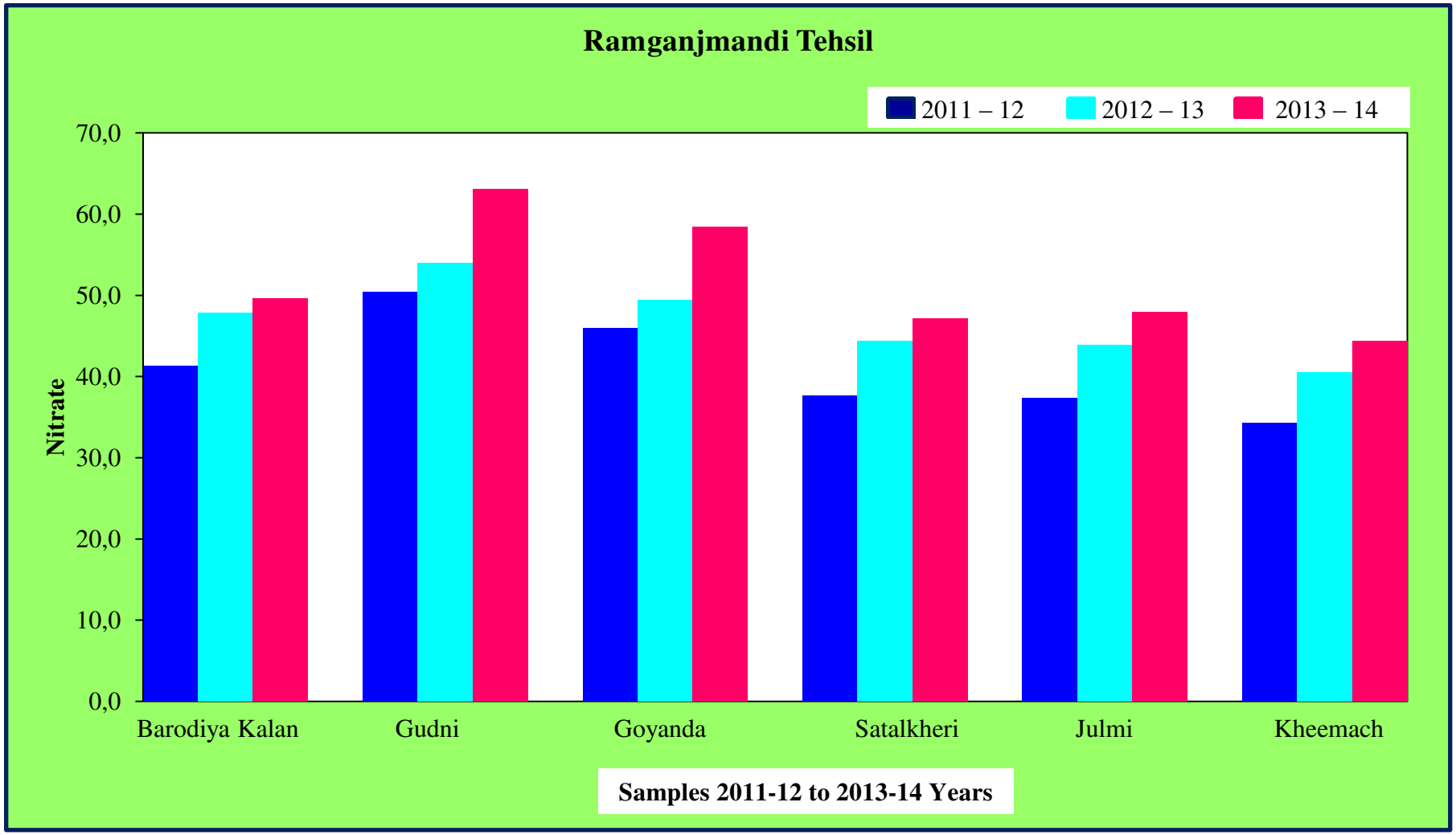

Fig 4G: Comparative Study of Nitrate in Ramganjmandi Tehsil for Three Years

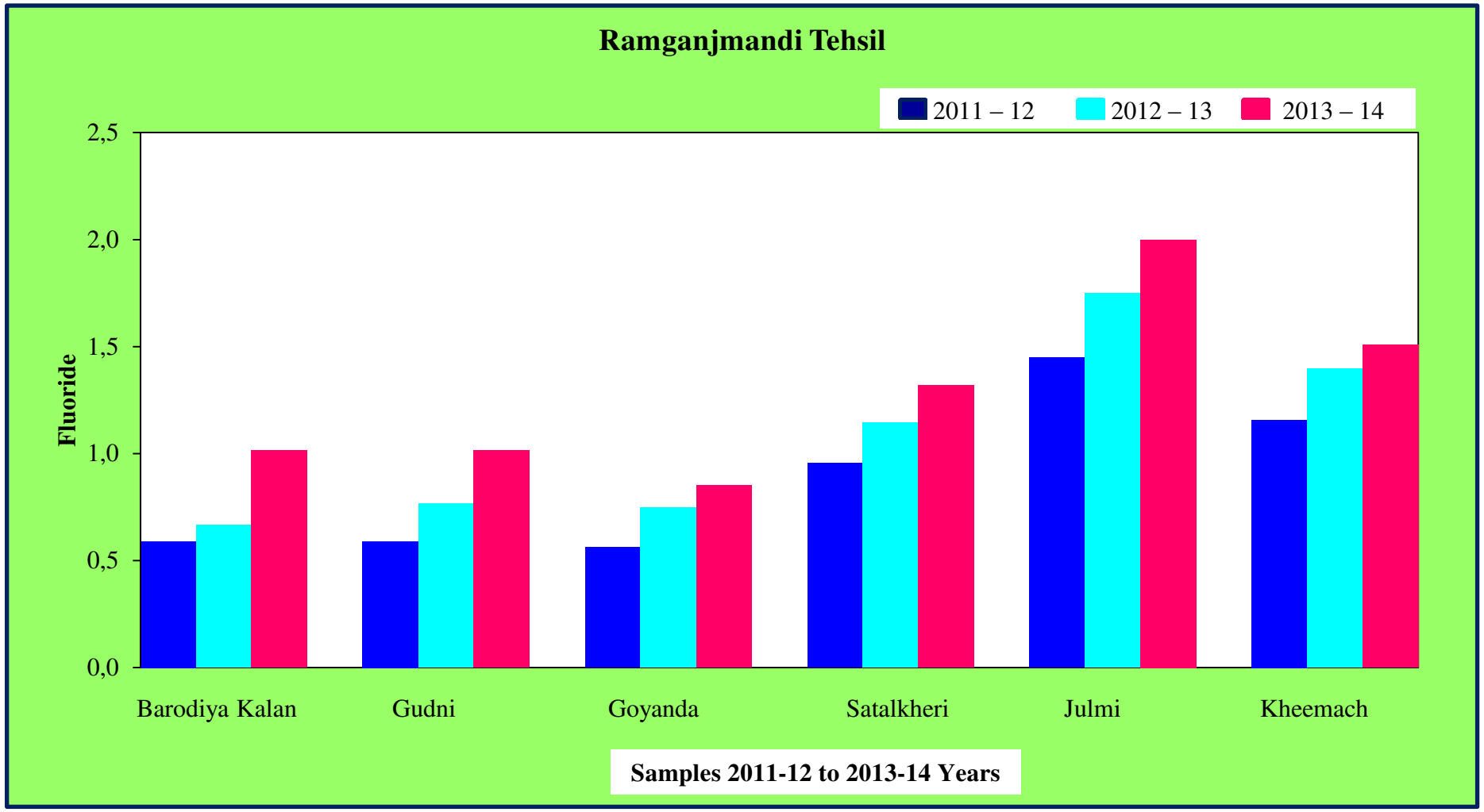

Fig 4H: Comparative Study of Fluoride in Ramganjmandi Tehsil for Three Years

SANGOD TEHSIL

The quantitative analysis of physicochemical parameters of six village of each tehsil of Kota district for the three years (from April, 2011 to March 2014) during four seasons (pre-monsoon, post-monsoon winter and spring) in morning and evening time period are shown in Table no - 29 to 34, annual analysis of heavy metals and of some physicochemical parameters carried out in pre-monsoon periods are presented in Table No – 35 and comparative studies are represented by Fig No – 5A to 5H.

WATER QUALITY PARAMETERS

pH Values

The permissible limit of pH values for drinking water is specified as 6.5 to 8.5 as per IS 10500. The pH values of groundwater samples were ranged from 5.9 (GWS/S/11-12-2011-12/post-monsoon) to 7.9 (GWS/S/7-2013-14/Pre-monsoon) with overall average value 7.2 in successive three years analysis.

Conductance

Conductance generally varies according to the season. In pre-monsoon period when water gets concentrated the conductance goes on higher side. The values of conductance of groundwater samples are ranged from 80 (GWS/S/12-2013-14/Post-monsoon) to 3434 µS (GWS/S/6-2012-13/pre-monsoon) with overall average value 1382.9µS of successive three years analysis, lower conductance in post monsoon period is due to dilution from rainwater.

Total Dissolved Solids

Water of high TDS is not suitable for use in boilers and hence restricted industrial use. The TDS of groundwater samples ranged from 43 (GWS/S/12-2013-14/post-monsoon) to 1954 (GWS/S/6-2013-14/pre-monsoon) mg/L with an average value of 764.3 mg/L. High TDS values observed in pre-monsoon season due to water concentrated. Lower values in post –monsoon was found due dilution of water with rainwater.

Total Alkalinity

According to IS 10500 the maximum allowable concentration of total alkalinity for drinking water is 600 mg/L. Total alkalinity of groundwater samples varies from 110 (GWS/S/12-2011-12/post-monsoon) mg/L to 720 (GWS/S/2-2012-13/Pre-monsoon) mg/L with overall average of 432.4 mg/L of successive three years analysis. Only 18 samples have higher values than the permissible limit of drinking water standard IS 10500.

Carbonate Alkalinity

In maximum number of analyzed samples carbonates alkalinity ND (Non detectable) and only in 5 samples carbonates alkalinity was detected. The values varied between 2 to 8 mg/L. The minimum value was observed in (GWS/S/7-2012-13/Post-monsoon) and maximum in (GWS/S/10-2011-12/Pre-monsoon).

Bicarbonates Alkalinity

Bicarbonates alkalinity ranged from 110 to 720 mg/L with an overall average of 432.3 mg/L in analyzed samples during successive three years. In sample (GWS/S/12-2011-12/post-monsoon) minimum value of bicarbonates alkalinity was observed and in sample (GWS/S/2-2012-13/Pre-monsoon) maximum value of bicarbonates alkalinity was observed.

Total hardness

The total hardness of groundwater samples ranged from 58 (GWS/S/12-2011-12/post-monsoon) to 996 (GWS/S/6-2011-12/pre-monsoon and 2012-13/pre-monsoon) mg/L with overall average of 475.9 mg/L of successive three years analysis. The anions responsible for hardness are bicarbonates, carbonates, sulphate and chloride. Hardness is temporary if it is associated mainly with carbonates and bicarbonates, and permanents if with sulphate and chloride.

Calcium Hardness

The calcium hardness of groundwater samples ranged from 59 to 628 mg/L with overall average of 256.7 mg/L of successive three years analysis. There is no definite trend in values of calcium hardness samples.

Magnesium Hardness

There is no definite trend in values of magnesium hardness in groundwater samples. Magnesium is determined as the difference between the total hardness and calcium hardness. The magnesium hardness ranged from 41 to 398 mg/L with overall average of 232.1 mg/L of successive three years analysis.

Sodium

Sodium values ranged from 25 to 220 mg/L and the average values of sodium was 133.0 mg/L in all of the studied samples of successive three- years. The maximum value of sodium examined in sample (GWS/S/6-2013-14/Pre-monsoon) and the minimum value of sodium measured in sample (GWS/S/12-2011-12/post-monsoon).

Potassium

Potassium values ranged from 1.4 to 21.3 mg/L and the average value of potassium was 8.8 mg/L in all of the studied samples of successive three-years. The maximum value of potassium examined in sample (GWS/S/6-2013-14/pre-monsoon).

Chloride

Chloride imparts a salty taste and some times higher concentration causes laxative effect in human beings. The values observed are within the specified limit of 250 mg/L as per IS 10500. The chloride concentration in groundwater samples varies from 15 to 370 mg/L with overall average of 126.2 mg/l of successive three years analysis.

Sulphate

The higher values of sulphates content may be contributed due to bio chemical, anthropogenic sources and industrial process etc. The sulphate ion concentration in groundwater samples ranged from 16 to 384 mg/L with overall average of 137.1 mg/L of successive three years analysis. The maximum allowable limit of sulphates in drinking water as per IS 10500 is 400 mg/L.

Nitrate

The maximum allowable limit of nitrate in drinking water as per IS 10500 is 45 mg/L. Nitrate content in groundwater samples varies from 9 to 107 mg/L with overall average of 45.5 mg/L of successive three years analysis. One third samples were having higher values than the permissible limit.

Fluoride

The fluoride ion concentrations in the study were within the specified limit and ranged from 0.2 to 2.1 mg/L with overall average of 1.0 mg/L in successive three years analysis. Water containing high fluoride concentration is not suitable for drinking water purpose. As per IS 10500 maximum fluoride concentration in drinking water is 1.50 mg/L.

Dissolved Oxygen

The data table reveals that DO values were ranged from 4.5 to 7.5 mg/L for the entire ground water samples and no major variations found in these values. The minimum value of DO was observed in sample GWS/Panahera/2011-12 and maximum value in sample GWS/Kamolar/2011-12.

Biological Oxygen Demand

Values ranged from 1.1 to 4.4 mg/L for the entire ground water samples. BOD was monitored in sample GWS/Dhoolet/2013-14 as minimum value and BOD was monitored in samples GWS/Shyampura/2013-14 as maximum values.

Chemical Oxygen Demand

Values were varied from 3.1 to 8.4 mg/L in the entire ground water samples. A maximum value of 6.4 mg/L was monitored in sample GWS/Dhoolet/2013-14.

Heavy Metals

Heavy metal is like Fe, Cd, Cu, Zn, Mn, and Pb were analyzed during for successive three years. Heavy metals like Cd, Cu, Mn and Zn were ND and those samples have some values of these metals were under permissible limits of IS 10500 and WHO. Fe values ranged from 0.01 to 0.18 mg/L. These values were within the prescribed limit. Pb was also ND at maximum sites except GWS/ Kurar, GWS/ Shyampura, GWS/ Morukalan and GWS/ Kamolar where values ranged from 0.02 to 0.21 mg/L and these all values were under permissible limits of IS 10500 and WHO the recommended standards.

CALCULATED INDICES

Aggressive Index (AI): Calculated values of aggressive index for all the samples analyzed in successive three years was ranged from 12.43 to 12.88 with an overall average of 12.69.

Langelier Saturation Index (LSI)

A calculated value of Langelier saturation index (LSI) was varied from -0.31to 0.12 with an overall average of -0.081 for all the samples analyzed in successive three years. Use of groundwater without any treatment may result in such manner; all samples result in mild scale/ encrustation. Data reveals that nature of groundwater samples of study area were neither severe corrosive nor severe scale/encrustation but usually mild conditioning is required.

Percentage Sodium (% Na)

Calculated values of percentage sodium (%Na) were ranged from 26.49 to 42.32 with overall average of 33.86 for all the samples analyzed in successive three

years. The minimum value was found in sample GWS/Dhoolet during 2011-12. Use of water having excess sodium percentage is not suitable not suitable for irrigational purpose. Data reveals that 17 samples were of good class, 1 sample were in permissible class.

Sodium Adsorption Ratio (SAR)

The calculated values of sodium adsorption ratio (SAR) were ranged from 1.98 to 3.17 with overall average of 2.64 for all the samples analyzed in successive three years. Classification of groundwater samples as per US agricultural norms reveals that all samples were of medium (S_2) class.

Residual Sodium Carbonate (RSC)

The calculated values of residual sodium carbonates (RSC) were ranged from -4.05 to 2.16 with overall average of -1.35 for all the samples analyzed in successive three years. Maximum value of RSC was calculated in sample GWS/Kurar-2012-13 and minimum value was in sample GWS/Kamolar-2012-13.

Exchangeable Sodium Percentage (ESP)

The calculated values of exchangeable sodium percentage (ESP) were ranged from 1.63 to 3.31 with overall average of 2.57 for all the samples analyzed in successive three years. Maximum value of ESP was calculated in sample GWS/Kurar-2013-14 and minimum value was in sample GWS/Kamolar-2011-12.

Table: 29

Physico-Chemical Parameters of Groundwater of Sangod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Kurar (GWS) S1-Morning S2-Evening	2011-12	Pre Monsoon	Morning	7.4	1427	814	602	ND	602	520	239	281	143	8.0	77	93	43	0.9
			Evening	7.4	1423	517	634	ND	634	544	260	283	144	7.6	75	90	41	0.8
		Post Monsoon	Morning	7.0	1097	612	401	ND	401	359	159	210	84	3.7	51	60	27	0.6
			Evening	7.0	1092	314	420	ND	420	382	167	215	85	3.4	49	59	26	0.6
		Winter	Morning	7.2	1198	672	510	ND	510	417	190	256	110	5.5	55	72	34	1.0
			Evening	7.2	1194	375	510	ND	510	440	200	240	110	5.3	53	71	33	1.1
		Spring	Morning	7.3	1296	740	558	ND	558	466	207	265	126	6.4	63	75	35	1.2
			Evening	7.3	1293	443	580	ND	580	488	228	260	127	6.1	61	74	34	1.4
	2012-13	Pre Monsoon	Morning	7.5	1447	836	680	ND	680	520	215	322	173	9.2	78	88	51	1.1
			Evening	7.6	1444	539	720	ND	720	544	240	326	174	8.9	76	85	49	0.9
		Post Monsoon	Morning	7.1	1112	637	451	ND	451	366	128	239	116	4.7	58	61	36	0.8
			Evening	7.1	1109	341	506	ND	506	390	148	262	118	4.3	56	58	34	0.7
		Winter	Morning	7.3	1218	700	580	ND	580	425	168	299	138	7.0	65	68	39	1.0
			Evening	7.3	1214	403	585	ND	585	448	183	275	139	6.7	61	64	37	1.0
		Spring	Morning	7.5	1307	770	618	ND	618	473	206	285	155	8.4	72	79	45	1.5
			Evening	7.5	1301	472	646	ND	646	496	207	299	157	8.0	69	75	43	1.4
	2013-14	Pre Monsoon	Morning	7.6	1387	792	676	ND	676	520	212	309	185	9.7	82	97	53	1.2
			Evening	7.7	1383	495	709	ND	709	544	233	311	186	9.2	79	93	52	1.1
		Post Monsoon	Morning	7.2	1059	593	457	ND	457	359	114	245	124	4.4	59	62	34	0.9
			Evening	7.3	1054	297	484	ND	484	381	134	247	125	4.1	58	62	33	0.9
		Winter	Morning	7.4	1160	656	526	ND	526	417	150	267	145	6.6	67	85	39	1.1
			Evening	7.5	1157	361	556	ND	556	439	170	269	146	6.4	65	82	39	1.0
		Spring	Morning	7.6	1241	719	606	2	604	463	173	289	166	8.8	73	84	47	1.4
			Evening	7.6	1236	423	634	ND	634	485	194	291	167	8.7	71	81	47	1.4

Note: All Values Except pH & EC are in mg/L.

Table: 30

Physico-Chemical Parameters of Groundwater of Sangod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Shyampura (GWS) S3-Morning S4-Evening	2011-12	Pre Monsoon	Morning	7.3	2211	1255	411	ND	411	779	457	322	140	13.9	255	269	67	0.9
			Evening	7.3	2216	1254	436	ND	436	719	398	321	142	13.9	221	241	63	0.9
		Post Monsoon	Morning	6.9	1883	1054	211	ND	211	613	359	254	90	10.0	230	239	52	0.4
			Evening	6.9	1887	1053	217	ND	217	553	299	252	82	10.1	198	202	48	0.5
		Winter	Morning	7.1	1993	1120	274	ND	274	674	394	280	103	11.6	235	252	61	0.6
			Evening	7.1	1996	1118	298	ND	298	614	336	299	123	11.6	228	245	57	0.8
		Spring	Morning	7.2	2085	1183	336	ND	336	724	422	302	119	12.3	246	259	61	1.0
			Evening	7.2	2090	1180	382	ND	382	663	371	307	151	12.2	238	249	58	1.1
	2012-13	Pre Monsoon	Morning	7.4	2221	1278	475	ND	475	779	431	348	170	15.4	255	264	75	1.1
			Evening	7.5	2227	1279	510	ND	510	719	372	346	199	15.5	241	256	71	1.0
		Post Monsoon	Morning	7.0	1901	1074	301	ND	301	628	347	292	114	11.3	231	222	58	0.5
			Evening	7.0	1906	1074	330	ND	330	568	289	280	116	11.3	181	202	55	0.6
		Winter	Morning	7.2	2013	1136	380	ND	380	690	394	304	136	13.5	237	240	62	0.7
			Evening	7.2	2017	1135	411	ND	411	630	328	302	174	13.4	232	234	59	0.9
		Spring	Morning	7.3	2108	1197	441	ND	441	736	409	346	152	14.9	247	253	68	1.0
			Evening	7.3	2113	1196	476	ND	476	677	351	326	193	14.6	240	242	65	1.1
	2013-14	Pre Monsoon	Morning	7.5	2164	1234	484	ND	484	779	428	350	183	15.8	260	274	78	1.3
			Evening	7.5	2169	1233	557	3	554	719	370	349	211	16.2	239	239	74	1.1
		Post Monsoon	Morning	7.0	1838	1041	312	ND	312	615	350	290	125	9.9	230	236	58	0.7
			Evening	7.0	1844	1039	376	ND	376	554	267	286	165	10.2	205	212	55	0.7
		Winter	Morning	7.2	1947	1102	367	ND	367	676	391	313	142	12.3	242	259	65	0.9
			Evening	7.2	1952	1103	420	ND	420	615	335	322	180	12.7	237	255	61	0.8
		Spring	Morning	7.4	2047	1167	433	ND	433	717	421	333	162	14.7	254	266	72	1.3
			Evening	7.4	2051	1161	538	ND	538	656	361	331	212	15.2	242	230	69	1.3

Note: All Values Except pH & EC are in mg/L.

Table: 31

Physico-Chemical Parameters of Groundwater of Sangod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Kamolar (GWS) S5-Morning S6-Evening	2011-12	Pre Monsoon	Morning	7.2	3284	1855	373	ND	373	977	548	398	179	18.4	370	379	95	0.5
			Evening	7.2	3410	1930	427	ND	427	996	599	397	182	18.8	368	383	96	0.6
		Post Monsoon	Morning	6.8	2954	1651	180	ND	180	825	486	310	119	15.1	337	346	80	0.2
			Evening	6.8	3079	1725	210	ND	210	844	430	310	121	15.3	299	329	70	0.2
		Winter	Morning	7.0	3069	1714	262	ND	262	886	508	348	140	17.2	342	358	88	0.6
			Evening	7.0	3193	1789	305	ND	305	905	557	349	143	17.5	346	364	90	0.7
		Spring	Morning	7.1	3157	1773	324	ND	324	933	531	371	156	18.0	352	365	89	0.7
			Evening	7.1	3280	1848	401	ND	401	953	581	372	174	18.2	356	369	91	0.9
	2012-13	Pre Monsoon	Morning	7.4	3309	1878	504	ND	504	977	575	372	217	20.1	345	362	103	0.8
			Evening	7.4	3434	1954	489	ND	489	996	625	370	210	20.5	368	377	105	0.8
		Post Monsoon	Morning	7.0	2984	1672	280	ND	280	813	468	272	152	15.8	300	310	87	0.5
			Evening	7.0	3108	1748	283	ND	283	832	561	271	155	16.1	343	345	88	0.4
		Winter	Morning	7.2	3094	1736	420	ND	420	875	541	361	189	18.3	345	348	90	0.6
			Evening	7.2	3218	1812	376	ND	376	894	584	310	177	18.7	350	352	92	0.6
		Spring	Morning	7.3	3184	1791	491	ND	491	924	563	365	206	19.6	337	348	97	0.9
			Evening	7.4	3306	1867	428	ND	428	942	607	336	194	20.0	360	365	98	1.0
	2013-14	Pre Monsoon	Morning	7.5	3250	1837	519	ND	519	977	577	370	218	20.7	320	381	105	0.9
			Evening	7.5	3376	1914	501	ND	501	996	628	369	220	21.3	370	384	107	0.9
		Post Monsoon	Morning	7.0	2919	1633	305	ND	305	819	516	273	157	15.3	300	345	86	0.6
			Evening	7.0	3045	1710	296	ND	296	839	566	274	160	15.7	344	347	88	0.5
		Winter	Morning	7.3	3035	1689	390	ND	390	880	538	312	199	17.4	329	368	92	0.9
			Evening	7.2	3160	1766	363	ND	363	901	587	313	180	17.9	353	370	94	0.7
		Spring	Morning	7.4	3120	1743	417	ND	417	929	563	337	211	20.0	359	370	100	1.0
			Evening	7.4	3245	1820	438	ND	438	950	611	338	202	20.6	363	373	102	0.9

Note: All Values Except pH & EC are in mg/L.

Table: 32

Physico-Chemical Parameters of Groundwater of Sangod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Panahera (GWS) S7-Morning S8-Evening	2011-12	Pre Monsoon	Morning	7.7	929	540	527	ND	527	391	198	193	135	5.6	51	65	30	1.3
			Evening	7.6	930	537	541	ND	541	395	204	191	136	5.5	48	63	28	1.3
		Post Monsoon	Morning	7.2	590	332	332	ND	332	243	116	126	76	1.9	23	33	13	0.7
			Evening	7.1	591	330	348	ND	348	246	122	124	76	1.8	19	28	11	0.8
		Winter	Morning	7.4	703	404	417	ND	417	301	152	149	100	3.7	29	45	22	1.0
			Evening	7.4	703	403	429	ND	429	305	156	149	101	3.7	26	44	21	0.9
		Spring	Morning	7.6	788	459	482	ND	482	352	179	174	117	4.1	39	52	23	1.3
			Evening	7.5	788	457	497	ND	497	356	184	173	117	4.3	36	48	21	1.1
	2012-13	Pre Monsoon	Morning	7.8	949	566	588	ND	588	391	175	216	164	7.5	52	61	38	1.5
			Evening	7.7	951	563	602	ND	602	395	181	214	165	6.7	49	58	36	1.4
		Post Monsoon	Morning	7.4	607	357	378	2	376	226	72	154	109	2.8	28	30	21	1.2
			Evening	7.3	610	355	391	ND	391	230	78	152	109	1.9	25	27	19	0.9
		Winter	Morning	7.6	710	431	465	ND	465	284	106	179	130	5.5	35	37	25	1.4
			Evening	7.5	712	429	480	ND	480	289	112	176	131	4.5	32	33	23	1.2
		Spring	Morning	7.7	816	491	529	ND	529	335	134	200	148	6.9	41	47	31	1.7
			Evening	7.6	817	490	543	ND	543	339	141	198	149	6.0	38	45	29	1.4
	2013-14	Pre Monsoon	Morning	7.9	904	519	591	ND	591	391	173	219	174	8.4	57	71	40	1.7
			Evening	7.8	905	515	605	ND	605	395	178	217	175	7.6	54	68	38	1.5
		Post Monsoon	Morning	7.4	580	317	378	ND	378	235	80	156	112	3.0	33	37	21	1.4
			Evening	7.3	579	312	393	ND	393	240	87	154	112	2.1	30	34	19	1.0
		Winter	Morning	7.6	682	389	450	ND	450	294	115	179	133	5.6	39	57	27	1.7
			Evening	7.5	683	384	464	ND	464	299	122	178	133	4.6	37	55	25	1.2
		Spring	Morning	7.8	772	448	526	ND	526	347	146	201	153	8.4	50	61	34	2.1
			Evening	7.7	772	442	541	ND	541	353	154	199	154	7.5	47	58	32	1.5

Note: All Values Except pH & EC are in mg/L.

Table: 33

Physico-Chemical Parameters of Groundwater of Sangod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Dhoolet (GWS) S9-Morning S10-Evening	2011-12	Pre Monsoon	Morning	7.5	994	580	593	ND	593	425	242	213	135	5.3	50	65	30	1.1
			Evening	7.5	1008	590	589	8	581	424	233	222	137	6.0	56	71	33	1.2
		Post Monsoon	Morning	7.0	669	370	389	ND	389	266	151	146	77	2.1	23	33	13	0.8
			Evening	7.0	684	380	380	ND	380	266	141	156	79	2.8	28	37	16	0.8
		Winter	Morning	7.2	775	445	475	ND	475	329	188	172	101	3.7	30	46	20	1.1
			Evening	7.2	791	453	464	ND	464	329	179	181	103	4.4	35	52	23	1.2
		Spring	Morning	7.4	851	498	541	ND	541	381	215	197	117	4.5	40	53	21	1.7
			Evening	7.4	866	504	527	ND	527	380	209	202	119	5.0	47	59	24	1.7
	2012-13	Pre Monsoon	Morning	7.6	1007	604	656	ND	656	425	218	237	166	6.6	51	60	38	1.2
			Evening	7.6	1022	614	645	ND	645	424	209	246	168	7.6	57	66	41	1.4
		Post Monsoon	Morning	7.2	672	390	435	ND	435	261	117	175	109	2.3	30	33	23	1.0
			Evening	7.2	686	400	424	ND	424	261	108	183	111	3.4	37	38	26	1.0
		Winter	Morning	7.4	776	463	526	ND	526	325	157	199	131	5.2	39	40	27	1.4
			Evening	7.4	792	474	513	ND	513	325	148	207	133	6.1	45	47	29	1.3
		Spring	Morning	7.6	881	512	585	ND	585	377	188	220	148	6.4	47	53	33	1.8
			Evening	7.6	898	523	572	ND	572	378	181	227	149	7.4	54	60	36	1.8
	2013-14	Pre Monsoon	Morning	7.7	951	557	660	ND	660	425	216	239	175	7.1	54	70	41	1.3
			Evening	7.7	967	567	649	ND	649	424	207	248	178	8.2	61	75	44	1.6
		Post Monsoon	Morning	7.2	610	356	459	ND	459	277	128	179	113	1.9	30	33	22	1.1
			Evening	7.2	627	365	448	ND	448	276	119	187	116	3.1	36	39	25	1.2
		Winter	Morning	7.4	720	429	530	ND	530	341	170	201	133	4.8	38	55	29	1.6
			Evening	7.4	738	439	517	ND	517	340	161	210	136	5.9	44	62	32	1.6
		Spring	Morning	7.6	797	490	613	ND	613	393	203	221	153	7.2	44	55	35	2.1
			Evening	7.6	814	501	602	ND	602	393	195	230	155	8.2	51	62	38	2.0

Note: All Values Except pH & EC are in mg/L.

Table: 34

Physico-Chemical Parameters of Groundwater of Sangod Tehsil

Name of Location	Year	Season	Sampling Time	pH	EC	TDS	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
Moru-Kalan (GWS) S11-Morning S12-Evening	2011-12	Pre Monsoon	Morning	6.3	442	283	250	ND	250	230	136	94	72	5.2	45	59	24	0.4
			Evening	6.3	438	280	231	ND	231	225	127	98	67	5.2	45	59	25	0.5
		Post Monsoon	Morning	5.9	120	67	151	ND	151	62	80	45	36	1.5	15	25	9	0.2
			Evening	5.9	115	64	110	ND	110	58	72	41	25	1.4	17	26	10	0.2
		Winter	Morning	6.2	233	142	198	ND	198	124	93	52	60	3.0	20	36	17	0.4
			Evening	6.1	229	139	200	ND	200	119	106	81	46	2.8	23	40	18	0.5
		Spring	Morning	6.3	307	192	251	ND	251	176	122	86	65	3.4	30	42	18	0.8
			Evening	6.3	302	189	231	ND	231	171	121	92	57	3.3	32	45	19	1.0
	2012-13	Pre Monsoon	Morning	6.5	470	304	313	ND	313	230	116	115	97	6.7	40	51	32	0.7
			Evening	6.4	465	303	352	ND	352	225	142	136	96	6.8	44	51	33	0.6
		Post Monsoon	Morning	6.1	146	87	189	ND	189	70	68	55	52	2.1	15	16	15	0.4
			Evening	6.0	140	87	149	ND	149	64	60	69	41	2.1	24	26	16	0.2
		Winter	Morning	6.3	258	158	223	ND	223	132	99	77	63	4.5	31	34	18	0.9
			Evening	6.2	251	158	237	ND	237	125	98	97	62	4.4	33	35	20	0.6
		Spring	Morning	6.4	352	204	307	4	303	185	122	114	89	5.7	43	50	23	1.3
			Evening	6.4	346	204	311	ND	311	179	130	126	85	5.8	45	51	25	0.9
	2013-14	Pre Monsoon	Morning	6.5	408	258	327	ND	327	230	113	117	108	7.5	42	60	30	0.8
			Evening	6.4	401	257	330	ND	330	225	133	122	107	7.7	50	65	36	0.8
		Post Monsoon	Morning	6.1	88	45	180	ND	180	73	59	69	55	2.7	20	27	17	0.5
			Evening	6.0	80	43	289	ND	289	68	90	76	90	2.8	23	27	18	0.4
		Winter	Morning	6.4	192	122	222	ND	222	135	96	81	68	5.1	29	47	22	1.1
			Evening	6.3	185	119	301	ND	301	129	120	92	90	5.1	31	48	23	0.9
		Spring	Morning	6.5	283	171	292	ND	292	186	122	100	90	7.2	39	50	31	1.6
			Evening	6.4	275	168	327	ND	327	181	135	119	92	7.3	40	51	32	1.3

Note: All Values Except pH & EC are in mg/L.

Table: 35

Annual Heavy Metals Concentration and Some Physicochemical Analysis of Sangod Tehsil

S. No.	Name of Location	Year	Parameters			Annual Trace Heavy Metal						Data Interpretation					
			DO	BOD	COD	Fe	Cd	Cu	Zn	Mn	Pb	AI	LSI	%Na	SAR	RSC	ESP
1	Kurar (GWS)	2011-12	6.1	3.3	5.6	0.04	ND	0.12	ND	ND	0.21	12.58	-0.22	34.96	2.35	0.86	2.15
		2012-13	6.8	3.5	5.8	0.03	ND	0.13	ND	ND	0.19	12.80	-0.05	39.58	2.91	2.16	2.94
		2013-14	6.7	3.8	5.2	0.01	ND	0.14	ND	ND	0.18	12.88	0.00	42.32	3.17	2.02	3.31
2	Shyampura (GWS)	2011-12	5.2	4.1	3.1	0.07	ND	0.16	0.03	0.14	0.05	12.52	-0.24	30.11	2.09	-0.20	1.79
		2012-13	5.3	4.2	3.3	0.06	ND	0.14	0.04	0.15	0.09	12.75	-0.04	34.39	2.60	-1.58	2.51
		2013-14	5.1	4.4	3.4	0.02	ND	0.15	0.07	0.13	0.07	12.83	0.04	36.39	2.81	-1.33	2.80
3	Kamolar (GWS)	2011-12	7.5	2.1	7.4	0.11	ND	0.02	0.09	ND	0.02	12.43	-0.31	27.07	1.98	-2.91	1.63
		2012-13	7.2	2.2	7.2	0.13	ND	0.01	0.08	ND	0.07	12.67	-0.09	32.51	2.61	-4.05	2.51
		2013-14	7.3	2.3	7.6	0.14	ND	0.03	0.06	ND	0.06	12.74	-0.02	34.64	2.86	-3.64	2.88
4	Panahera (GWS)	2011-12	4.5	4.2	6.1	0.17	ND	0.05	ND	0.04	ND	12.44	-0.31	27.50	2.14	-3.75	1.87
		2012-13	4.8	3.8	6.2	0.18	ND	0.06	ND	0.06	ND	12.74	-0.02	33.42	2.84	-2.50	2.85
		2013-14	5.7	3.7	6.8	0.17	ND	0.04	ND	0.07	ND	12.80	0.05	35.22	3.07	-3.04	3.16
5	Dhoolet (GWS)	2011-12	6.4	1.2	8.2	0.12	ND	ND	ND	ND	ND	12.48	-0.27	26.49	2.21	-2.48	1.95
		2012-13	6.2	1.3	8.3	0.10	ND	ND	ND	ND	ND	12.79	0.07	30.61	2.72	-1.45	2.67
		2013-14	6.1	1.1	8.4	0.09	ND	ND	ND	ND	ND	12.83	0.12	31.26	2.80	-2.13	2.79
6	Morukalan (GWS)	2011-12	7.1	2.4	3.1	0.02	ND	ND	ND	ND	0.08	12.55	-0.20	34.05	2.41	-0.94	2.24
		2012-13	6.8	2.6	3.3	0.08	ND	ND	ND	ND	0.11	12.78	-0.01	39.32	3.02	0.35	3.09
		2013-14	6.7	2.5	3.2	0.04	ND	ND	ND	ND	0.07	12.83	0.05	39.67	3.10	0.22	3.21

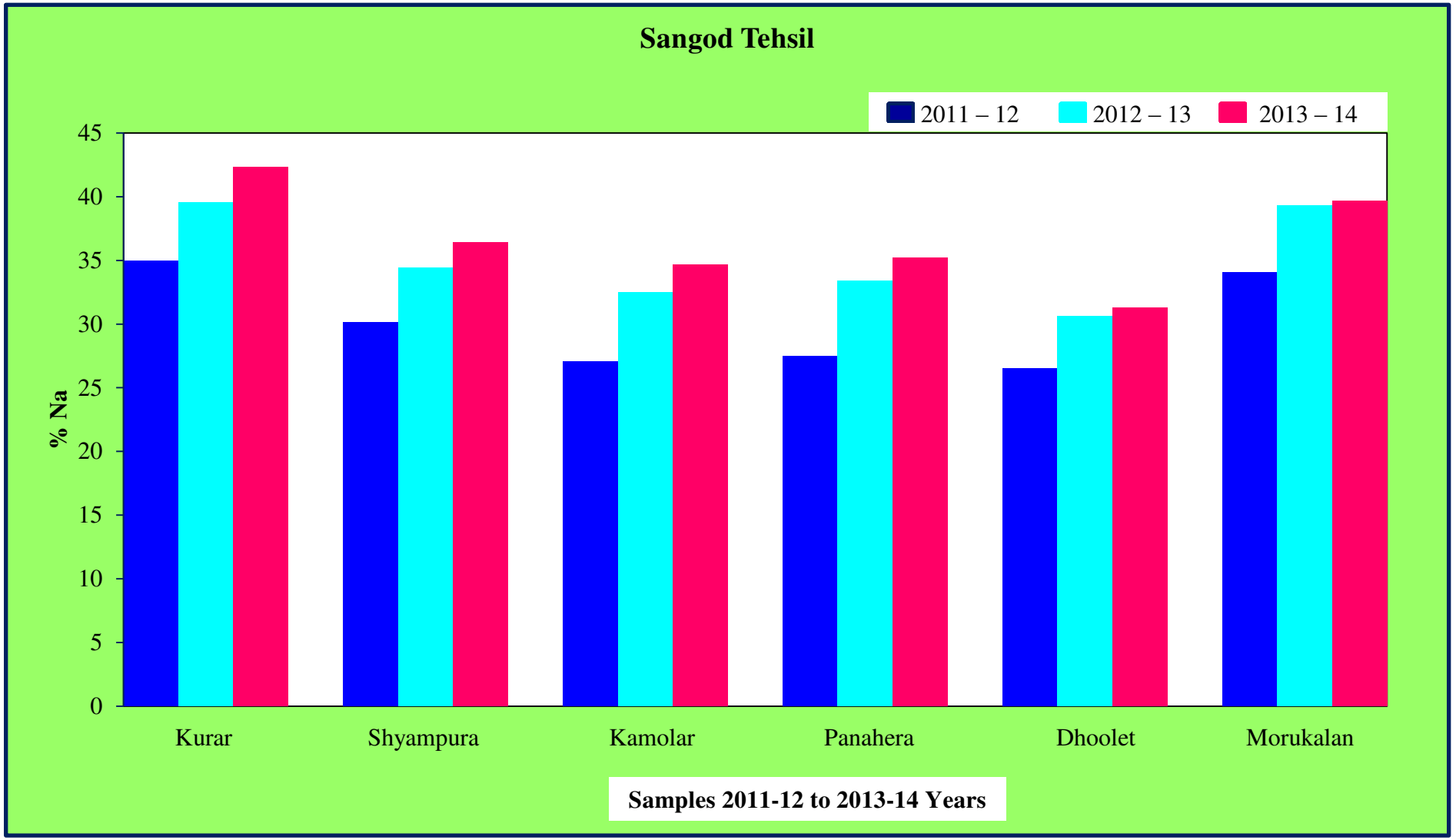

Fig 5A: Comparative Study of % Na in Sangod Tehsil for Three Years

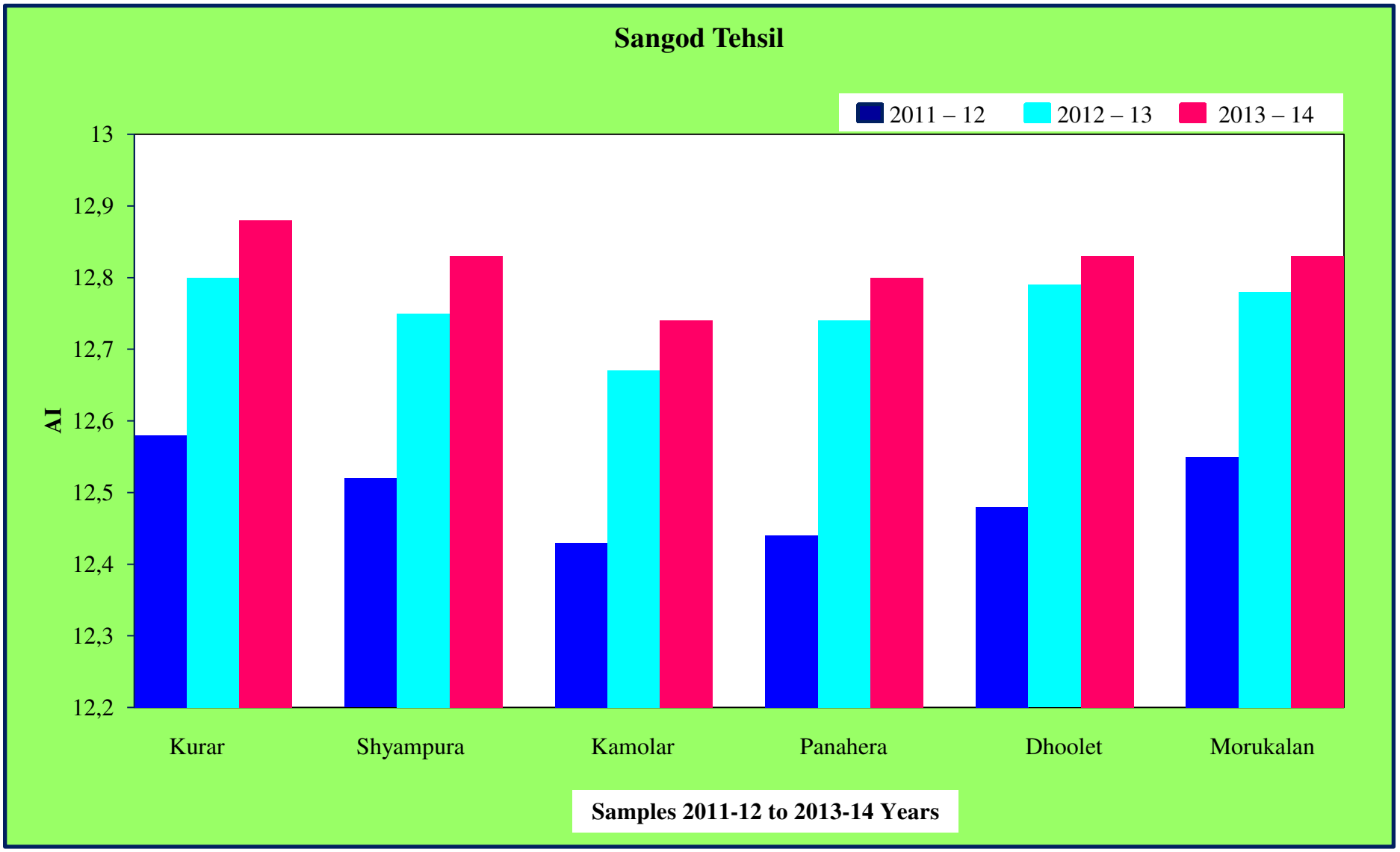

Fig 5B: Comparative Study of AI in Sangod Tehsil for Three Years

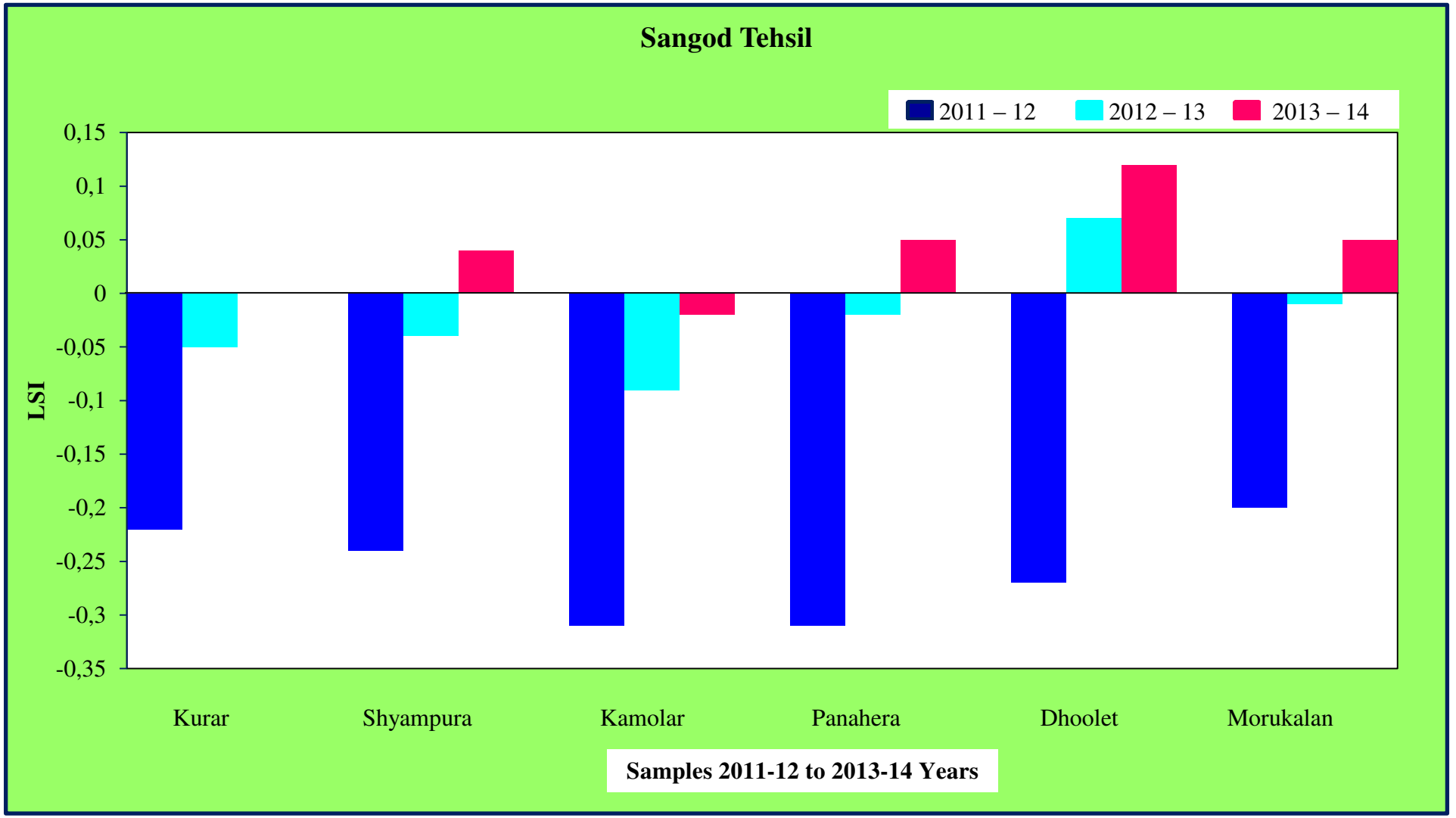

Fig 5C: Comparative Study of LSI in Sangod Tehsil for Three Years

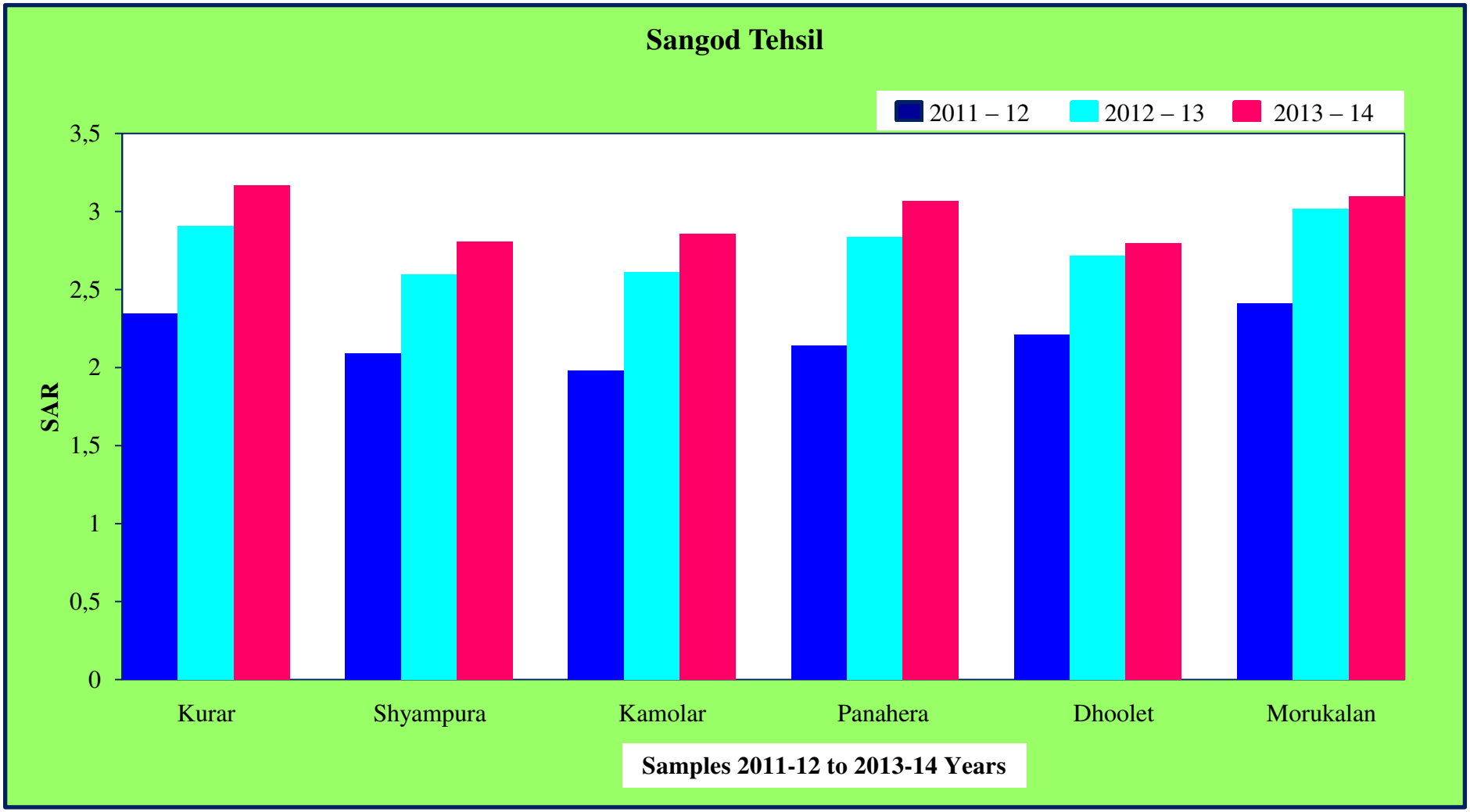

Fig 5D: Comparative Study of SAR in Sangod Tehsil for Three Years

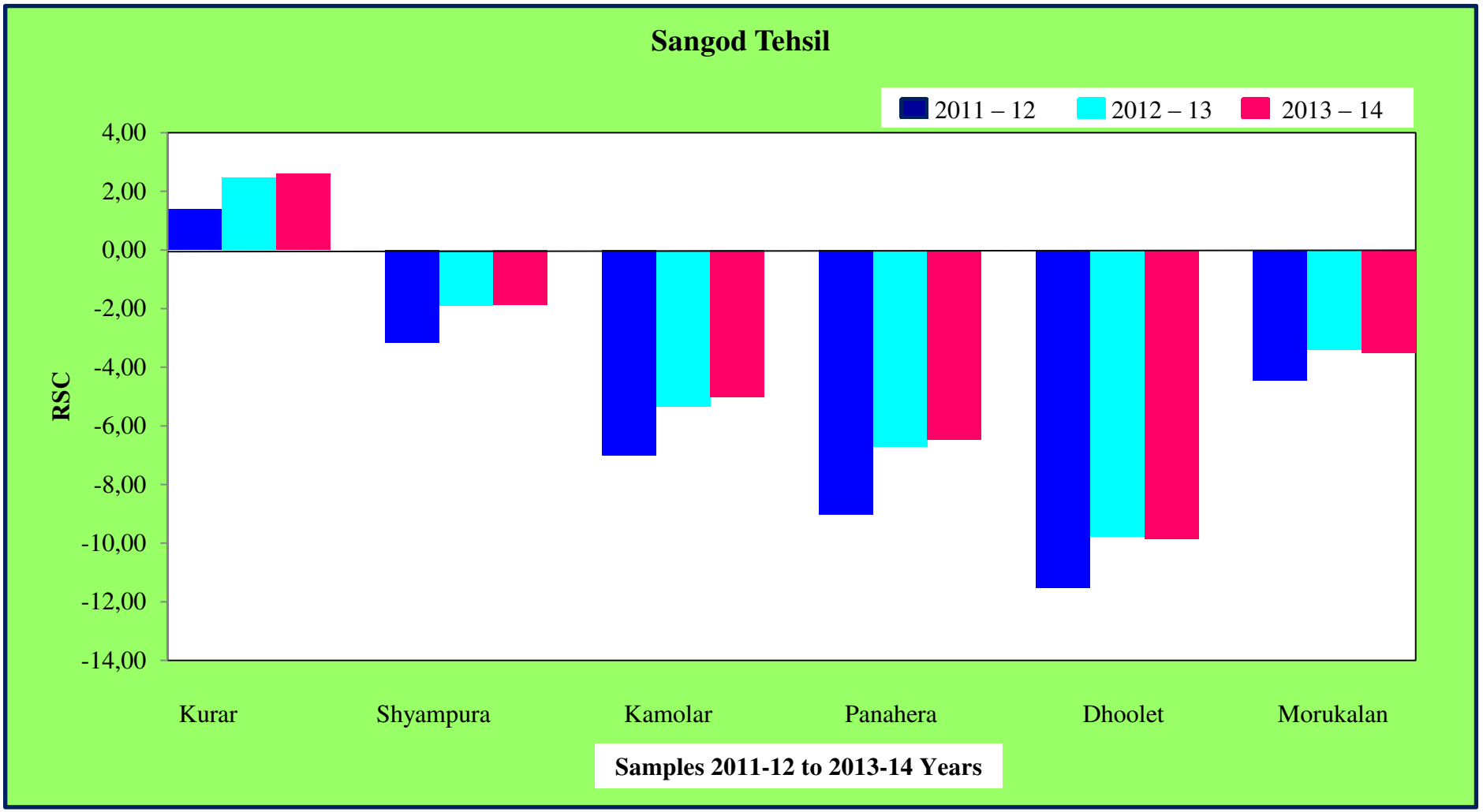

Fig 5E: Comparative Study of RSC in Sangod Tehsil for Three Years

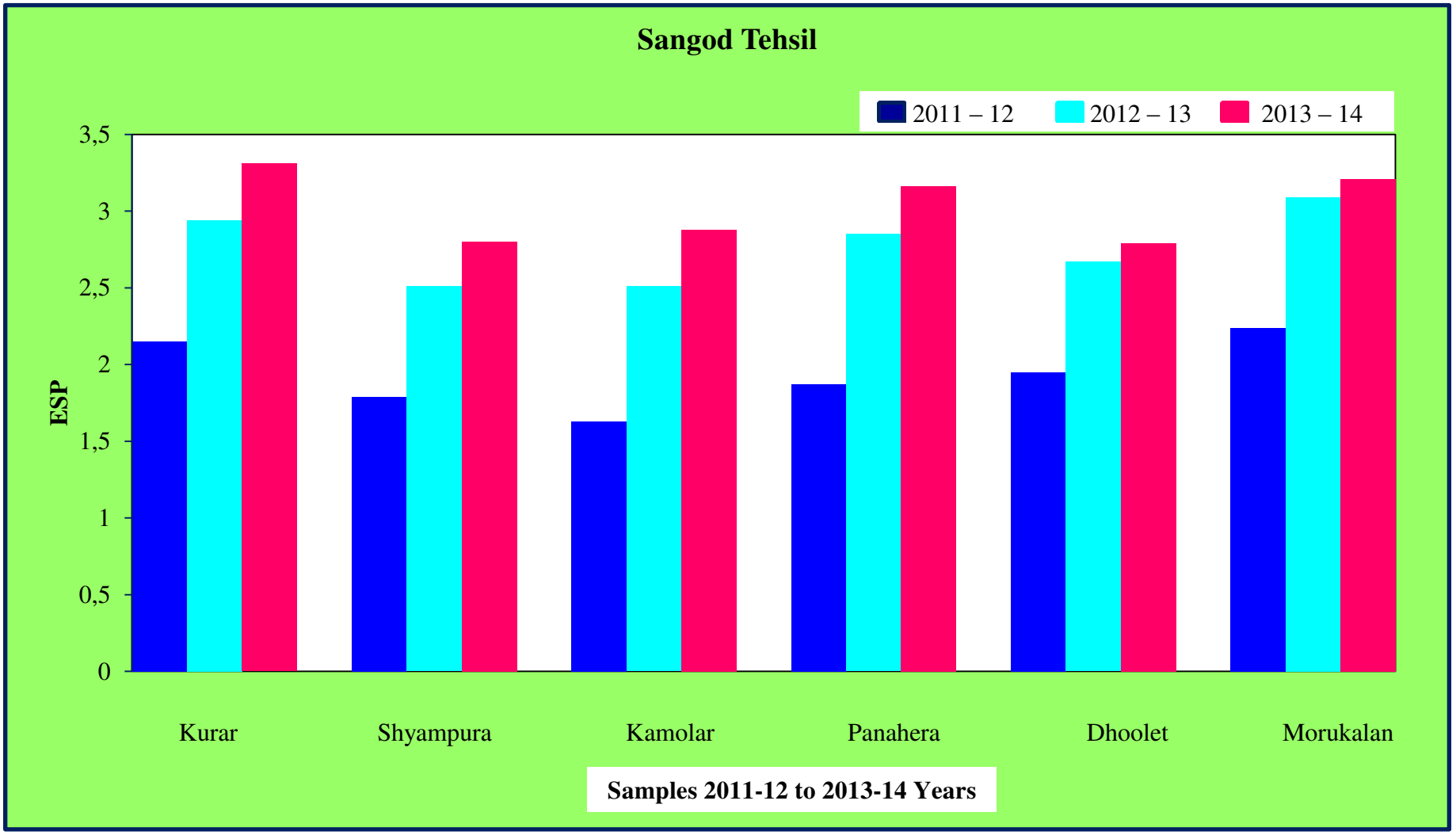

Fig 5F: Comparative Study of ESP in Sangod Tehsil for Three Years

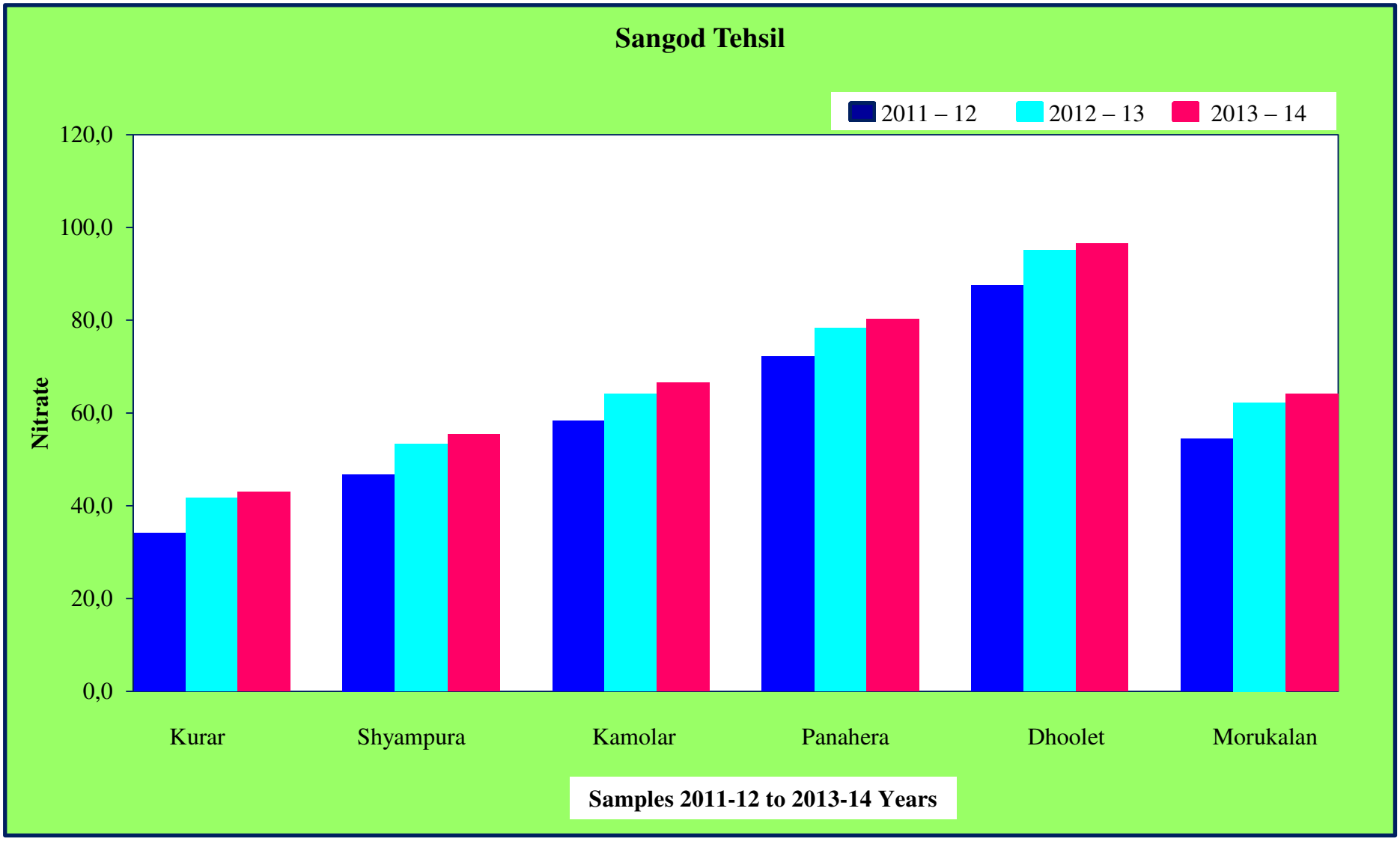

Fig 5G: Comparative Study of Nitrate in Sangod Tehsil for Three Years

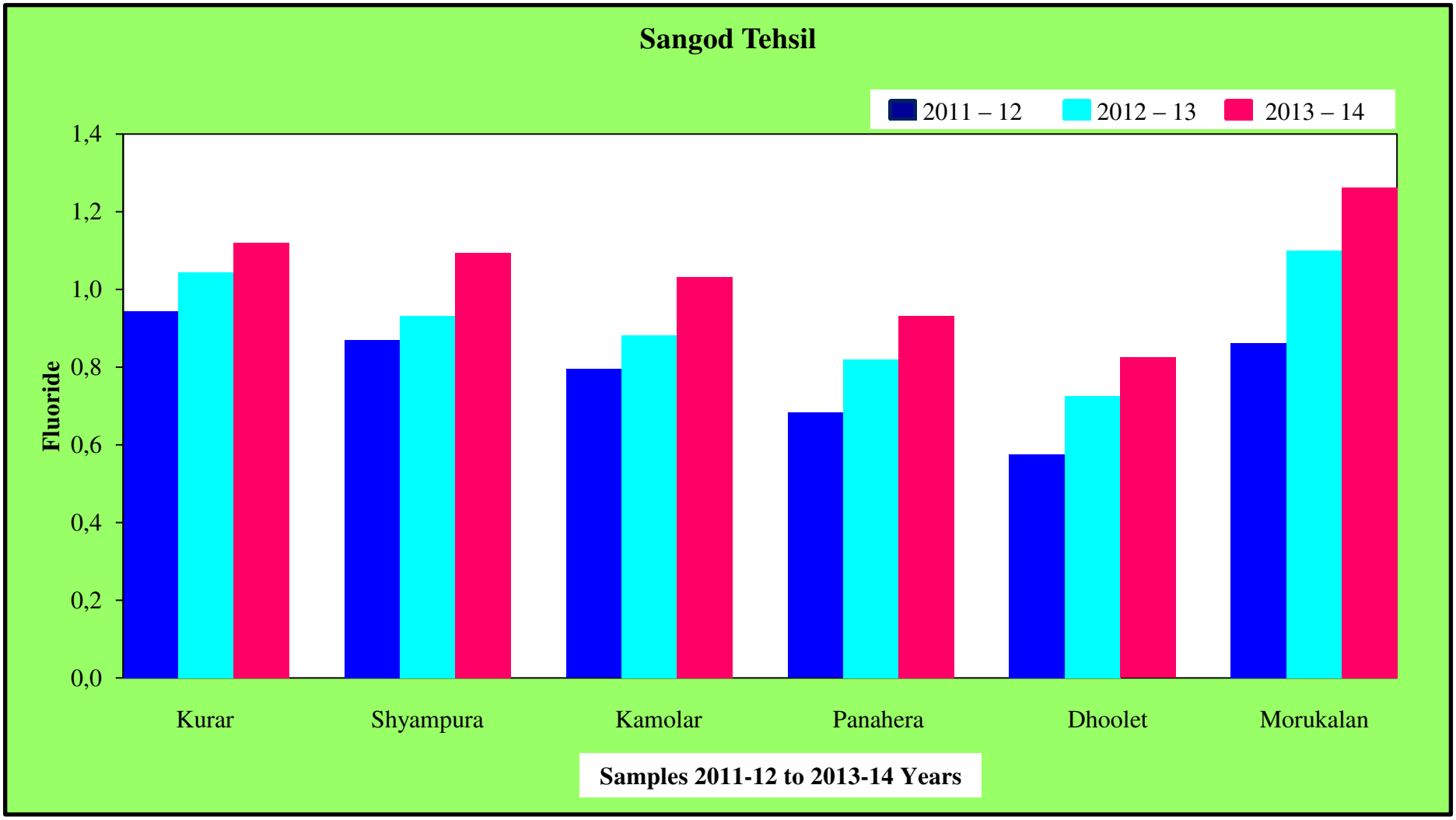

Fig 5H: Comparative Study of Fluoride in Sangod Tehsil for Three Years

CHAPTER 4

DISCUSSION
ON
FINDINGS

In this chapter the first section is discussion on findings and the second Section summarizes viable recommendation and suggestions about the ground water quality status.

DISCUSSION ON FINDINGS

The purpose of this chapter is to discuss the findings which have emerged from the research work. The physicochemical assessment of groundwater samples of five tehsils of Kota District was used to evaluate the suitability of groundwater for drinking, industrial and agricultural purpose. A sensitivity analysis showed that now a day's groundwater quality deteriorated. Main factors affect the hydrochemistry of groundwater of Kota District is wastewater and agriculture activities. Groundwater source is considered the main water supply source for all kind of human usage in the villages of five tehsils of Kota district (domestic, agricultural and industrial).

Comparison of Ground-Water Quality of five tehsil of Kota District

Data reveals that all the five tehsil's are polluted to some extent but Digod tehsil is most polluted as indicated by a very high values of physicochemical parameters. Data also indicates that in all the five tehsil EC, TDS, TA, CO_3^{2-} , K^+, SO_4^{2-} and NO_3^- were found to be within the permissible limits as prescribed by BIS standards but all five tehsil pH, HCO_3^-, Ca^{2+}, Mg^{2+} and F^- beyond the permissible limits as prescribed by WHO and BIS. Data also reveals that the water quality of all five tehsil is poor for drinking and irrigation purpose. To improve the quality of water of all the five tehsil's there should be continuous monitoring of the pollution level.

Digod tehsil data revealed that there were considerable variations in the examined samples. The results of analysis of various physico-chemical parameters of groundwater, may be defined that the concentration of EC, TDS, TA, CO_3^{2-} , K^+, SO_4^{2-} and NO_3^- were within the permissible limit but nearly one third (1/3) of the studied samples (32%) were high in pH, HCO_3^-, Ca^{2+}, Mg^{2+}

and F^- which suggest the poor water quality of these water samples. From the results of Itawa tehsil , it may be defined that the values of TDS, TA, CO_3^{2-}, K^+, SO_4^{2-} and NO_3^- were within the permissible limit but nearly half the studied samples (48%) were high in pH, EC, HCO_3^-, Ca^{2+}, Mg^{2+}, Na^+, F^- which suggest the poor water quality of these water samples. Ladpura tehsil results can be interpreted, that the values of pH, TDS, TA, CO_3^{2-} , HCO_3^-, K^+, SO_4^{2-} and NO_3^- were within permissible limits but nearly half of the studied samples (58%) were high in EC, TH, Na^+, Ca^{2+}, Mg^{2+} and F^- which suggest the poor water quality of these water samples. Ramganjmandi Tehsil results can be drawn out the values of pH, EC, TDS, TA, CO_3^{2-} , HCO_3^-, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-} and NO_3^- were within permissible limits but nearly half the studied samples (52%) were high in HCO_3^-, Na^+, Ca^{2+}, Mg^{2+} and F^- which suggest the poor water quality of these water samples. From the observation, Sangod Tehsil it may easily be concluded that the concentration of pH, TDS, TA, CO_3^{2-}, K^+ and SO_4^{2-} were within the permissible limit but some of the studied samples (29%) were high in EC, TH, HCO_3^-, Ca^{2+}, Mg^{2+}, NO_3^-, and F^- which suggest the poor water quality in these water samples.

Finally it can be drawn out that general characteristics of groundwater samples were unsuitable for household, irrigation, and commercial purpose during the study period. However, treatment can be suggested for high pH, EC, Na^+, Ca^{2+}, Mg^{2+}, HCO_3^-, F^- and NO_3^- values specifically. Water-quality samples collected for this study indicate that all five tehsil ground water contains higher concentrations of calcium, magnesium, bicarbonate, and fluoride.

Seasonal effects of groundwater quality were mostly observed for parameters such as Ca, Mg, at all five tehsil sampling sites. Results of all the five tehsils revealed that TDS (Total Dissolved Solids) values are higher in Post Monsoon season as compared to Pre Monsoon due to leaching of various salts into Post Monsoon ground water. In most of the tehsil, nitrate concentration increases in post monsoon. Study of water quality parameters revealed that the drinking water in most locations of Digod and Ramgajmandi tehsil area was found to be highly contaminated. The dissolved oxygen content varies significantly throughout the day. Dissolved oxygen levels are normally lowest around morning and highest at some time in the evening.

RECOMMENDATIONS AND SUGGESTIONS

RECOMMENDATIONS

There are various measures which made to control the water pollution;

1. Proper planning should be executed before drawing the underground water.
2. Ground water must be pretreated so as to ensure less health threats.
3. People awareness campaigning should be organized/implemented by the government and non-government organization.
4. The overall quality of groundwater is poor and this situation needed urgent treatment.
5. Programs should be implemented to monitor the bore wells and hand pumps exceeding the limitation of guidelines
6. Domestic waste and agricultural activities affect groundwater quality so the monitoring of fertilizers and pesticides is needed.
7. Water quality index is a manual way in order to understand the water quality.

SUGGESTIONS

1. The household discharged water should be treated so that it become Environ.ly safe. In order to prevent water pollution, human and animal excreta should be prevented from mixing with water sources.
2. Treatment of wastes before discharge is necessary. Toxic material must be treated chemically and converted into harmless materials. Factories should try to recycle the waste water.
3. Laws relating to pollution should be strictly enforced on people.
4. The water that flows through the drainage system should be properly treated. Harmful pollutants should be removed, before they can are introduce into groundwater.
5. Big cities usually have treatment plants which filter out undissolved materials but dissolved remain as such.

6. Chemical treatment can be given to separate out unwanted dissolved chemicals materials.
7. The treated water can be used for farming / cleaning purpose.
8. Washing, bathing of animals in the pond that is used by human should not be done.
9. Washing of clothes and bathing of animals make the pond water dirty and unsuitable for use.
10. Drinking water kept undercover in a clean place. One should not put his hands into the drinking water containers.
11. The water meant for drinking should be made microorganisms free boiling generally kills microorganism prior to use.
12. Sanitation system must be improved. The benefits of cleanliness on human health need to be understood.
13. People should be aware about the effect of water pollution. Voluntary organizations can render door-to-door services to educate the people about Environ. problems.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Abdul Jameel A, Evaluation of drinking water quality in Tiruchirapalli, India J of Env Health, 44, 108 -112, **2002.**
2. Abdul Saleem, Mallikarjun N. Dandigi and Vijay Kumar, "Correlation-regression model for physicochemical quality of groundwater in the South Ind. city of Gulbarga", African J. of Environ. Science and Technology, 6(9), 353-364, **2012**.
3. Adhikary, P P, Chandrasekharan, H, Chakraborty, D, Kamble, Assessment of groundwater pollution in West Delhi, India using geostatistical approach Environ. Monitoring and Assessment, 154 (1-4), 41-52, **2009.**
4. Adnan S and Iqbal J, Spatial Analysis of the Groundwater Quality in the Peshawar District, Pakistan, Procedia Engineering, 70, 14-22, **2014.**
5. Aghadeh N and Mogaddam, Assessment of Groundwater Quality and its Suitability for Drinking and Agricultural uses in the Oshnavish Area, Northeast of Iran, J. of Environ. protection, 1, 30-40, **2010.**
6. Agrawal V and Jagetia M, Hydrogeo-chemical assessment of ground water quality in Udaipur City, Rajasthan, India, 151-154, **1997.**
7. Almasri M N and Kaluarachchi J J, Assessment and management of long-term nitrate pollution of ground water in agriculture-dominated watersheds. J. of Hydrology, 295, 225-245, **2004.**
8. Amaaliya N K and Kumar S P, Carried out ground water quality status by water quality index method at Kanyakumari, (INDIA), 2(9), 76-82, **2013.**
9. American Public Health Association (APHA): (1998) American Water Works Association, Water Environment Federation (1998). Standard methods for examination of water and wastewater (20th ed.). New York, USA: American Public Health Association.

10. Annual Report of Public Health Engineering Departmet (PHED), Rajasthan, **1991.**
11. APHA., "Standard methods for the examination of water and wastewater", American Public Health Association, Washington, **1998.**
12. Appelo C A J and Postma D, Geochemistry, groundwater and pollution, Second Edition. Balkema, Leiden, the Netherlands, 683, **2005.**
13. Aravinda H B, Correlation coefficient of some physic-chemical parameters of river Tungabhadra, Karnataka, Pollution research, 17(4), 371- 375, **1991.**
14. Ashley R P and Burely M J, Controls on the occurrence of fluoride in the groundwater in the Rift Valley of Ethiopia, in H.Nash and G.J.H. McCall (eds) Groundwater Quality, 17th Special Report, Chapman and Hall, 45-54, **1994.**
15. Atta A I, and Razzak B I A, Chemical and physical analysis of some ground water sample in Al- Quti wells Hodiedah, Yemen. J. Iran. Chem. Res., 1, 141-144, **2008.**
16. Babu K N, Padmalal D, Maya K, Sreeja R and Arun P R, Quality of Surface and Ground Water Around Tile and Brick Clay Mines in the Chalakudy River Basin, Southwestern India. J. Geol. Soc. India, 69, 279-284, **2007.**
17. Backman B, Bodis D, Lahermo P, Rapant S, and Tarvainen T, Application of a groundwater contamination index in Finland and Slovakia, Environ. Geology, 36(1–2), 55–64, **1998.**
18. Balasubramanian A, Subramanian S, and Sastri J C V, HYCH - Basic computer program for hydrogeochemical studies, Proc. Vol. Nat. Sem. on water. Govt. of Kerala, Trivandrum, **1991b.**
19. Ballukraya P N and Ravi R, Characterization of groundwater in the unconfined aquifers of Chennai City, India. J. Geol. Soc. India, 54, 13-22, **1999.**
20. Banerjee A, Groundwater Fluoride Contamination: A Reappraisal. Geoscience Frontiers, 6, 277-284, **2015.**

21. Banerjee S, Das B, Umlong I M, Devi R R, Kalita H, Saikia L B, Borah K, Raul P K and Singh L, Heavy Metal Contaminants of Undergroundwater in Indo Bangla Border Districts of Tripura, India. International J. of ChemTech Research, 3, 516-522, **2011.**

22. Banerji A K, Importance of evolving a management plan for groundwater development in the Calcutta region of the Bengal basin in eastern India. Proc. Intn. symp. Groundwater resources and planning, Koblent, Germany, 45-54, **1983.**

23. Basavarajappa H T and Manjunatha M C, Groundwater Quality Analysis in Precambrian Rocks of Chitradurga District, Karnataka, India Using Geo-Informatics Technique. Aquatic Procedia, 4, 1354-1365, **2015.**

24. Belkhiri L, Boudoukha A and Mouni L, Groundwater quality and its suitability for drinking and agricultural use in Ain Azel plain, Algeria, J. of Geography and Regional Planning, 3(6), 151-157, **2010.**

25. BIS, "Drinking water specification", Bureau of Ind. Standards, New Delhi, IS: 10500, 11, **2003.**

26. Biswal S K, Maythi B and Behera J P, Ground water quality near ash pond of thermal power plant, Pollution research, 20 (3), 487-490, **2001.**

27. Bohlke J K, Groundwater recharge and agricultural contamination, Hydrogeol J., 10,153-179, **2002.**

28. Boominathan R and Khan S M, Effect of distillery effluents on pH, dissolved oxygen and phosphate content in Uyyakundan channel water, Environ. Ecology, 12, 850-853, **1994.**

29. Bouwer H, Integrated water management: Emerging issues and challenges, agricultural water management. 45, **2000.**

30. Brown R M, McClelland N I, Deininger R A and Tozer R G, A water quality index: Do we dare?", Water & Sewage Works, 117, 339–343, **1970.**

31. Bureau of Ind. standards: Analyses of water and wastewater, BIS, Institution, Now Delhi **(1991).**

32. Central Ground Water Board, Guide on artificial Recharge to Groundwater, Western Region, Jaipur **(2002).**

33. CGWB, Groundwater year book, NCT, Delhi, Report, Central Ground Water Board, Ministry of Water Resources, Government of India, New Delhi **(2006).**

34. Chandra sekhar M and satya Prasad M V K, Regression Models for Assessment of Dissolved Pollutants in Krishna River, J. of Ind. water resource society, 25(4), **(2005).**

35. Chatterjee R, Gourab T and Paul S, Groundwater quality assessment of Dhanbad district, Jharkhand, India, Bulletin of Engineering Geology and Environment, 69(1), 137-141, **(2009).**

36. Chatterjee R, Gupta B K, Mohiddin S K, Singh P N, Shekhar S, Purohit R, Dynamic groundwater resources of National Capital Territory, Delhi: assessment, development and management options .Environ. Earth Sciences 59, 669-686, **2009.**

37. Chhatwal Gurdeep Raj, Advanced Physical Chemistry, Goel Publishing house, Meerut **(2002).**

38. Contaminant evaluation of boreholes water (drinking water sources) in Gambhiria village, Sagar (MP), National symposium on Advances in Environ. chemistry and green technologies, Organised by RJIT tekanpur, Gwalior, Sponsored by, M.P. Council science and technology, Bhopal, **2012.**

39. Craig E and Anderson M P, The effects of urbanization on groundwater quality – A Case Study. Groundwater. 17, 456-462, **1979.**

40. Cristina R, Pistea I, Calugar M, Martonos I and Ozunu A, Assessment of Ground Water Quality Status by using water quality index (WQI) Method in Tureni Village **(2012)**.

41. Dahiya S and Kaur A, Assessment of physical and chemical characteristics of underground water in rural areas of Tosham subdivision, Bhiwani-Haryana, International J. of Environment and pollution, 6(4), 281-288, **1999.**

42. Das Gupta M, Purohit K M, Jayita D, Assessment of drinking water quality of River Brahmani. J. Environ. Pollut. 8, 285-291, **2001.**

43. Das P K and Malik S D, Groundwater of Khatra region of Bankura district, West Bengal: Some chemical aspects in reference to its utilization, J Ind. Water Res Soc, 8(3), 31-41, **1988.**

44. Dash J R, Dash P C and Patra H K, A correlation and regression study on the ground water quality in rural areas around Angul-Talcher industrial zone, International J. of Environ. protection, 26(6), 550-558, **2006.**

45. Dass S, Agarwal M, Chaudhary Y S and Shrivastav R, A Study on Fluoride and other Water Quality Parameters of Ground Water of District Agra (U.P.). In: Subramanian, V. and Ramanathan, A.L. (Eds.), Proceedings of the International Workshop on Ecohydrology. Capital Publishing Company, New Delhi, India, 213, **2001.**

46. Datta N C and Gupta S S, Effect of artificial aeration on the hydrographic regime of pesticide treated aquatic system. Poll. Res., 15(4), 329-333, **1996.**

47. Datta P S and Tyagi S K, Major ion chemistry of groundwater in Delhi area: chemical weathering process and groundwater flow regime, J Geol Soc India 47, 179–188, **1996.**

48. Datta P S, Bhattacharya S K, Tyagi S K, Assessment of groundwater contamination from fertilizers in the Delhi area based on 18O studies on recharge of phreatic aquifers and groundwater flow paths of mixing in the Delhi area, J. of Hydrol 176, 25-36, **1996.**

49. Deshpande S M and Aher K R, Evaluation of groundwater quality and its suitability for drinking and agriculture use in parts of Vaijapur, district Aurangabad, MS, India", Research J. of Chemical Sciences, 2(1), 25- 31, **2012.**

50. Dinesh C, Fluoride and human health – cause for concern. Ind. J. Environ. Protect., 19(2), 81-89, **1999.**

51. Durvey V S, Sharma L L, Saini V P and Sharma B K, Hand book on the methodology of water quality assessment, Rajasthan Agriculture University, India, **1991.**

52. Foster S S D, Groundwater for development- overview of quality constraints. In: Nash H, McCall GJH (eds) Groundwater quality, Water Resources Bulletin, 28(3), 525-533, **1995.**

53. Gajendran C and Thamarai P, Study on statistical relationship between ground water quality parameters in Nambiyar River basin, Tamil Nadu, India, International J. on pollution research, 27(4), 679 – 683, **2008.**

54. Ganesh R H and Kale Y S, Quality of lentic waters of Dharwad district in north Karnataka, Ind. J. Environ. Hlth., 37(1), 52-56 **1995.**

55. Garg M, Kavita V K and Malik R A, Groundwater quality in some villages of Haryana India: focus on fluoride and fluorosis, J. of Hazardous Material, 106B, 85-97, **2004.**

56. Gawas A D, Lokhande P B and Mujawar H A, Characterization of wastewater by correlation and regression method, International J. of Environ. protection, 27(12), 1117-1120, **2007.**

57. Gebbie P, Water Stability – Water does it mean and how do you measure it?, 63rd Annual Water Industry Engineers and Operators Conference, Civic Center – Warrnambool, 50–58, **2000.**

58. Ghosh S, Chakraborty S, Roy B, Banerjee P and Bagchi A, Assessment of Health Risks Associated with Fluoride-Contaminated Groundwater in Birbhum District of West Bengal, India. J. of Environ. Protection Science, 4, 13-21, **2010.**

59. Gillison R J and Patmont C R, Lake phosphorus loading from septic systems by seasonally perched groundwater. J. Water Pollut. Con. Fed., 55, 1297-1304, **1983.**

60. Gopal R and Gosh P K, Fluoride in drinking water – Its effects and removal, Def. Sci. J., 35(1), 71-88, **1985.**

61. Gorde S P and Jadhav M V, Assessment of Water Quality Parameters, A Review, J. of Engineering Research and Applications, 3(6), 2029-2035, **2013.**

62. Ground water Department, Ground water Resources of Jaipur District, Ground water Department, Jaipur, 131, **1995.**

63. Ground Water Scenario of India 2009-10, Central Ground Water Board Ministry of Water Resources Government of India, Faridabad, **2010.**

64. Groundwater Quality Status of Rajasthan, Public Health Engineering Department, Jaipur, Rajasthan, **2001.**

65. Guideline for Drinking Water Quality Recommendation, World Health Organization, Geneva, 1, 1- 130, **1994.**

66. Guidelines for Drinking-Water Quality.2nd Edn. Vol., 1.World Health Organization, Geneva, WHO, **1993.**

67. Gupta G S, Gupta M K, Gupta Alpana and Gupta Anjani, Assessment of physic-chemical characteristics of hand pumps water of Banda city, Ind. J. Environ. Prot., 34, 51-54, **2014.**

68. Gupta N, Bisht S and Patra B A, Physico-Chemical Analysis of Drinking Water Quality from 32 locations in Delhi, J. of Ind. Water Works Association, **2010.**

69. Gupta S C, G S Rathore and Doshi C S, Fluorida distribution in ground waters of South-eastern Rajasthan. Ind. J. Environ. Health, 35(2), 97-106, **1993.**

70. Gupta S K and Deshpande R D, Water for India in 2050: first-order assessment of available options, Current Science, 86 (9), 1216-24, **2004.**

71. Gyananath G, Islam S R and Shewdikar S V, Assessment of Environ. Parameter on ground water quality. Ind. J. Environ. Prot. 21, 289-294, **2001.**

72. Handa B K, Hydrochemical zones of India. Proc. Seminar on groundwater development, Roorkee, 439-450, **1986.**

73. Helmet F, Enviromental Chemistry, 1st Edition, Ivy Publishing House, New Delhi, **2003.**

74. Hem J D, Study and Interpretation of the Chemical Characteristics of Natural Waters, 2254, 3rd ed. Scientific Publ., Jodhpur, India, 263, **1991.**

75. Hemant P and Limaye S N, Assessment of Physico-Chemical Quality of Groundwater in rural area nearby Sagar city, MP, India. Advances in Applied Science Research. Pelagia Research Library 3, 555-562, **2012.**

76. Hemant P and Limaye S N, Study of seasonal variation in groundwater quality of sagar city (india) by principal component analysis, J chem., 8, 2000-2009, **2011.**

77. Hijab M, Belel Z A and Kachalla A K, The Physico-Chemical Quality of Groundwater in Geidam Nigeria, International J. of Engineering Research & Technology, 1(7), **2012.**

78. Horton R K, An index number system for rating water quality, J. Wat. Poll. Control Fed., 37, 300-305, **1965.**

79. Indian standard specification for drinking water. IS:10500, Ind. Standard Institute, India, ISI, **1983.**

80. Indian standards for drinking water Speciation. Bureau of Ind. Standard, New Delhi (BIS 10500), **2012.**

81. Jain C K, Assesment of ground water quality for drinking water purpose, District Nainital, Utarkhanda, India, Environ monit Assess, springer, 166, 663-673, **2009.**

82. Jameel A A and Hussain A Z, Assessment of ground water quality on bank of Uyyakonda channel of river Cauvery at Tiruchirappalli, Ind. J. Environ. Prot. 27, 713-716, **2007.**

83. Jeyaraj T, Padmavathy S, Shirley S, and Jebakumar S, Correlation among water quality parameters for ground water samples of Bharathi Nagar of Tiruchirapalli City, International J. of Environ. protection, 22(7), 755-759, **2001.**

84. Jha A N and Verma P K, Physico- chemical properties of drinking water in town area of Godda district under Santal Pargana (Bihar), India. Poll. Res. 19(2): 75 85, **2000.**

85. Kaplay R D and Patode H S, Groundwater pollution due to industrial effluent at Tuppa, New Nanded, Maharashtra. India Environ. Geol. 46, 871– 882, **2004.**

86. Karanth K R, Ground water assessment, development and management. Tata McGraw-Hill Publishing Company Limited, New Delhi, India, **1997.**

87. Karunakaran K, Statistical study on physicochemical characteristics of groundwater in and around Namakkal, Tamilnadu, India. E-J. of Chemistry, 6(3), 909-914, **2009.**

88. Kaur R and Singh R V, Assessment for different groundwater quality parameters for irrigation purposes in Bikaner city, Rajasthan, J. of applied sciences in Environ. sanitation, 6 (3), 385-392, **2011.**

89. Kavitha R and Elangovan K, Review article on Ground water quality characteristics at Erode district, (India), of I.J.E.S., 1(2), **2010.**

90. Kemmer E D, The Nalco water Handbook, Mc Graw Hill, New York, 4, 33–15, **1979.**

91. Keshvan K G and Parameswari R, Evaluation of ground water quality in Kancheepuram, Ind. J. of Environ. protection, 25(3), 235-239, **2005.**

92. Khaiwal R and Garg V K, Distribution of fluoride in groundwater and its suitability assessment for drinking purpose. Int. J. Environ. Hlth. Res., 16, 163-166, **2006.**

93. Khan T A, Trace Elements in the Drinking Water and their possible Health Effect in Aligarh City, India". J. of Water Resource and Protection, 3, 522-530, **2011.**

94. Kumar D and Ahmed S, Seasonal behaviour of spatial variability of groundwater level in a granitic aquifer in monsoon climate. Current Sci., 84(2), 188-196, **2003.**

95. Kumar M and Kumar R, Assessment of Physico-Chemical Properties of Ground Water in Granite Mining Areas in Goramachia, Jhansi, UP,

India. International Research J. of Environment Sciences. 2(1), 19-24, **2013.**

96. Kumar M, Ramanathan A l, Rao M S, Kumar B, Identification and evaluation of hydrogeochemical processes in the groundwater environment of Delhi, India. Environ Geol 50, 1025-1039, **2006.**

97. Kumar R, Singh R D and Sharma K D, Water Resources of India, Current Science, 89, 794-811, **2005.**

98. Kumar S, Among water quality parameters for ground water in Barmer district, Ind. J. of Environ. protection, 13(7), 487-489, **1993.**

99. Loganathan D, Kamatchiammal S, Ramanibai R, Jayakar S D, Saroja V, Indumath S, Status of groundwater at Chennai city, India. Ind. J Sci Technol. 4(5), **2011.**

100. Machiwal D and Jha M K, Identifying Sources of Groundwater Contamination in a Hard-Rock Aquifer System Using Multivariate Statistical Analyses and GIS-Based Geostatistical Modeling Techniques. J. of Hydrology: Regional Studies, 4, 80-110, **2015.**

101. Majumdar D and Gupta N, Nitrate pollution of ground water and associated human health disorders. Ind. J. of Environ. Health 42, 28–39, **2000.**

102. Mangukiya R, Bhattacharya T, and Chakraborty S, Quality Characterization of Groundwater using Water Quality Index in Surat city, Gujarat, India, International Research J. of Environment Sciences, 1(4), 14-23, **2012.**

103. Mariappan V, Prabakaran P, Rajan M R and Ravichahandran A D, A systametic study of water quality index among the physic chemical characteristic of ground water in and around Thanjavur Town. IJEP, 25, 551-555, **2005.**

104. Mark W R, Ximing C, and Sarah A C, World Water and Food to 2025, dealing with security, International Food Policy Research Institute, NY. Washington DC, USA, **2002.**

105. Meena A K, Mishra G K, Rai P K and Nagar P N, Treatment of heavy metals contaminated ground water using GAC, National conference on carbon (Indo- carbon 2001) Anand proceeding, 15-19, **2001.**

106. Mishra A, Vasishta D B, Sevak N, Shah P, Patel K and Patel C, Comparative Study of Physico- Chemical and Microbial Parameters on Lotic And Ground-Waters In Selected Outlying Areas of Central Gujarat. J. Chem. Pharm. Res. 2(4), 174-177, **2010.**

107. Mishra P C and Patel R K Study of the pollution load in the drinking water of Rairangpur, a small tribal dominated town of North Orissa. Ind. J. Environ. Ecoplanning, 5(2), 293-298, **2001.**

108. Mitra B K, Spatial and Temporal Variation of Ground Water Quality in Sand Dune Area of Aomori Prefecture in Japan, **1998.**

109. Mohan R N and Choudhary G C, Heavy metals in the groundwater of non-industrial area. Poll. Res., 17(2), 167-168, **1998.**

110. Mohan R, Singh A K, Tripathi J K and Chowdhary G C, Hydrochemistry and quality assessment of groundwater in Naini Industrial Area, Allahabad district, Uttar Pradesh. J. Geol. Soc. India, 55, 77-89, **2010.**

111. Mohapatra U K and Singh B C, Trace metals in drinking water from different sources in old capital city of Cuttak". Ind. J. of Environ. Health, 41(2), 115–120, **1999.**

112. Mohrir A and Sarin R, Surface and groundwater quality assessment in Bina region, IJEP, 22(9), 961-969, **2002.**

113. Mondal N C and Saxena V K, Assessment of groundwater pollution due to tannery industries in and around Dindigul, Tamilnadu, India. Environ Geol, 48,149-157, **2005.**

114. Mor S, Bishnoi M S, Bishnoi N and R, Assessment of ground water quality in Jind city, Ind. J. of Environ. Protection, 23(6), 673-679, **2003.**

115. Mukherjee S, Kumar B A and Kortvelyessy L, Assessment of groundwater quality in the south 24-parganas, west Bengal coast, india J. of Environ. Hydrology, 13, 15, **2005.**

116. Mumtazuddin S, Azad A K, Bharti P and Ranjan R, Physico-chemical analysis of groundwater of the Budhi Gandak belt in Muzaffarpur district, India, International Research J. of Environment Sciences, 1(1), 7-11, **2012.**

117. Murli K, Swasthik R D and Elangovan R, Assessment of ground water quality in coimbatore south Taluk ,coimbatore District,India, A WQI approach ,10 (4), 521-524, **2011.**

118. Muthukumaravel K, Evaluation of Ground Water Quality in Perambalur, Ind. J. of Environ. Sciences, 14(1), 47-49, **2010.**

119. Nagarajappa D P, Rajappa B, Manjappa S, and Puttaiah E T, Physico chemical analysis of underground water of Harihara taluk of Davanagere district, Karnataka, India", Advances in applied science research, 2(5), 143-150, **2011.**

120. Naik S and Purohit K M, Studies on water quality of river Brahmani in Sundargarh district, Orissa. Ind. J. Environ. Ecoplanning, 5(2), 397-402, **2001.**

121. Nair G A, Bohjuari J A, Muftab A and Premkumar K, Assessment of the well water quality of Benghaziliya, IJEP, 25, 481- 489, **2005.**

122. Narayanpethkar A B and Deshpande A S, Groundwater quality study of bhandarkav the village of Solapur district, Maharastra, India, J. of applied Hydrology, 3-4, 37-46, **2011.**

123. Niranjan K, Reddy G S, Varma K S, Reddy S S, Reddy R M, Ground Water Quality Assessment of Wailpalli Nalgonda, Ind. J. of Environ. Sciences, 15(1), 69-76, **2011.**

124. Nirdosh P, Ahmed A, Sureshbabu H, Kottureshwar N M, Jayashree M., and Nijalingappa J, Study on the Physico-Chemical characteristics of ground water of Gulbarga City (Karnataka) International J. of Applied Biology & Pharmaceutical Technology, 1(2), 519, **2010.**

125. Nirmala B, Suresh Kumar B V, Suchetan P A and Shetprakash M, seasonal variations of Physico –chemical characteristics of ground water sample of Mysore city, Karnataka, India. Int. J. Env.sci., 1(4), 43-49, **2012.**

126. Nitrate and nitrite in drinking water Background document for development of WHO Guidelines for Drinking-water Quality, WHO, **2007.**

127. Parihar S S, Kumar A, Kumar A, Gupta R N, Pathak M, Shrivastav A, and Pandey A C, Physico- Chemical and Microbiological Analysis of Underground Water in and Around Gwalior City, MP, India. Research J. of Recent Sciences. 1(6), 62-65, **2012.**

128. Patel P and Bhatt S, A Fluoride Contamination in Groundwater of Patan District, Gujarat, India, International J. of Engineering Studies, 1(2), 171– 177, **2010.**

129. Patil N, Ahmed A, Sureshbabu H, Kottureshwar N M, Jayashree M and Nijalingappa J, Study on the physico -chemical characteristics of ground water of Gulbarga city, Karnataka, India. Int.J. Appli. Biopharm. Tech., 1 (2), 518-523, **2010.**

130. Patil V T and Patil P R, Physicochemical Analysis of Selected Groundwater Samples of Amalner Town in Jalgaon District, Maharashtra, India. E-J. of Chemistry, 7(1), 111-116, **2010.**

131. Physico-chemical Analysis of Ground Water Samples of Sagar city with respect to water soluble pollutants (National Seminar of Environment protection & waste management , Organised by, Govt. P.G. College, Bina, Sponsored by, U.G.C., New Delhi).

132. Pradhan S K, Patnaik D and Rout S P, Groundwater quality index for groundwater around a phosphatic fertilizers plant, Ind. J Environ Protect., 21(4), 355-358, **2001**.

133. Prajapati R and Mathur R, Statistical studies on the ground water at the rural areas of Sheopurkalan, Madhya Pradesh, J. of ecotoxial Environ. monit., 15(1), 47-54, **2005.**

134. Prevention and Cotrol of Fluorosis in India: (Health Aspects) (Ed. Susheeia, A. K.) Rajiv Gandhi National Drinking Water Mission, 1, **1993.**

135. Raja G and Venkatesan P, Assessment of Groundwater Pollution and its impact in and around Punnam Area of Karur District, Tamilnadu, India, E-J. of Chemistry, 7(2), 473-478, **(2010).**

136. Raja R E, Physico- Chemical Analysis of Some Groundwater Samples of Kotputli Town Jaipur, Rajasthan. Ind. J Environ Prot. 22(2), 137, **2002.**

137. Rajankar P N, Wate S R, Tambekar D H and Gulhane S R, Assessment of Ground Water Quality using water quality index(WQI) in Wardha Maharashtra, J. of Environ. Science and Sustainability, NEERI, 1(2), 49-54, **2013.**

138. Ramachandra S A Narayanan and Pundarikathan N V, Nitrate and pesticide concentrations in groundwater of cultivated areas in north Madras. Ind. J. Environ. Hlth., 33(4), 421-424, **1991.**

139. Ramakrishnalah C R, Sadashivalah C and Ranganna G, Studies on Ground Water Quality in slums of Visakhapatnam, Asian J. of chemistry, 21(6), 4246-4250, **2009.**

140. Ramakrishniah C R, Sadashivaiah C, and Ranganna G, Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, E-J. of Chemistry, 6(2), 523-530, **2009.**

141. Ramappa R and Suresh T S, Quality of groundwater in relation to agricultural practices in Lokapavani river basin, Karnataka, India. Proceedings of International Seminar on Applied Hydrogeochemistry, Annamalai University, 136–142, **2000.**

142. Ramesh K and Soorya V, Hydrochemical Analysis and Evaluation of Groundwater Quality in and around Hosur, Krishnagiri District, Tamil Nadu, India. International J. of Research in Chemistry and Environment. 2(3), 113-122, **2012.**

143. Ramesh M, Dharmaraj E, Raj B J R, Physico-chemical characteristics of ground water of Manachanallur Block Trichy, Tamilnadu, India. Advances in Applied Science Research. 3(3), 1709-1713, **2013.**

144. Rao N S, Studies on Water Quality Index in Hard rock Terrain of Guntur District, Andhra Pradesh, India, National Seminar on

Hydrogeology of Precambrian Terrains and Hard Rocks Areas, Dharwad, 129-134, **1997.**

145. Rao P M and Yadav Y S, Water Quality Studies on Kolleru Lake and Its Infalling Drains of A.P., India, Water Pollution. APH Publishing Corporation, New Delhi, 171, **2004.**
146. Rao R, Satyanarayan T and Machiraju P V S, Assessment of ground water quality for application in Kakinada Coast, Der Chemica Sinica. 3, 287-291, **2012.**
147. Rao S N and Suryanarayana K, Ground water quality in a coastal area: A case study from Andhra Pradesh, India. Environ. Geology, 48(4-5), 543-550, **2005.**
148. Rao S N, Seasonal variation of groundwater quality in a part of Guntur District andhra Pradesh, India. Environ. Geol., 49, 413-429, **2006.**
149. Ratnakanth Babu M J, Assessment of Groundwater Pollution in Parts of Guntur District Using Remote Sensing & GIS, International J. of Earth Sciences and Engineering, 4(6), 1024-1030, **2011.**
150. Raval V H and Malik G M, Physico-chemical characteristics of ground water in around Surat City (India). J. Environ. Sci. and Engg. 52, 343-348, **2010.**
151. Ravichandra R and Chandana O S, Study on evaluation on groundwater pollution in Bakkannaplem, Visakhapatnam", Nature, Environment and Pollution Technology, 5(2), 203-207, **2006.**
152. Ravindra K and Garg V K, Appraisal of ground water quality for drinking purpose in Hisar city (India) with special reference to fluoride. Int. J. Env. Hlt. Res, in press **2005.**
153. Raviprakash S, and Rao G K, The chemistry of ground water in Paravada area with regard to their suitability for domestic and irrigational purposes, Ind. J. of Geochemistry, 4, 39-54, **1989.**
154. Ray D and Sanyal P B, Physico-chemical quality of drinking water in Rohtas district of Bihar. Environ. Monitoring and Assessment. 61, 387- 398, **2000.**

155. Reddy M, Status of groundwater quality in Bangalore and Its environs. Groundwater (Minor Irrigation), Bangalore, 44 – 52, **2003.**

156. Rengaraj S and Ramalingam V, Groundwater quality in suburban regions of Madras city, India. Poll. Res., 15(4), 325-328, **1996.**

157. Richard L A, Diagnosis and improvement of saline soils, U.S. Dept. Agriculture, Handbook 60, 160, **1954.**

158. Rosin K G, Kaur R, Singh S D, Singh P and Dubey D S, Groundwater Vulnerability to Contaminated Irrigation Waters, A Case of Peri-Urban Agricultural Lands around an Industrial District of Haryana, India. Procedia Environ. Sciences, 18, 200-210, **2013.**

159. Rout C and Sharma A, Assessment of drinking water quality: A case study of Ambala cantonment area Haryana India, Inter. J. of Environ. Sci. 2, 933-945, **2011.**

160. Ryznar John W, An Index for determining the amount of Calcium Carbonates Scale formed by a water, Nalco Chemical Company, One Nalco Centre, Naperville, Illnois, USA, **1986.**

161. Sabahi E A l, Rahim S A, Zuhairi W Y W, Nozaily F A l, Alshaebi F, The Characteristics of Leachate and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen. American J. of Environ. Sciences 5 (3), 256- 266, **2009.**

162. Sabata B C and Nayar M P, River pollution in India: A case study of Ganga river, 33, **1995.**

163. Saha D and Sikdar P K, Geochemical Evolution of Groundwater in the Pleistocene Aquifers of South Ganga Plain, Bihar. Jour. Geol. Soc. India, 71, 473-482, **2008.**

164. Saralakumari D and Rao P R, Endemic fluorosis in the village Ralla, Anantapuram in Andra Pradesh. An epidemiological study. Fluoride, 26(3), 177-180, **1993.**

165. Sawant R, Jadhav S D, Godghate A and Patil S R, Ground water quality of Gadhinglaj Tahsil of Maharastra., 10(4), 613- 616, **2011.**

166. Sawyer C N, McCarty P. L. and Gene F P, Chemistry for Environ. engineering. IVth Ed., Tata McGraw-Hill, New Delhi, **2000.**

167. Scottish Development Department, Towards cleaner water. Edinburgh: HMSO, Report of a River Pollution Survey of Scotland, **1975.**

168. Shahnawaz M and Singh K M, Ground Water Quality of Piro and Jagdishpur Blocks of Bhojpur District: A Middle Gangatic Plain. International J. of Pharmaceutical Quality Assurance. 1(1), 9-12, **2009.**

169. Shankar B S, Balasubramanya N, Reddy M T M, Impact of industrialization on groundwater quality –a case study of Peenya industrial area, Bangalore, India. Environ. Monitoring and Assessment, 142,263-268, **2008.**

170. Sharma H and Kaur B K, Environ. chemistry. Goel Publishing House, Meerut. **1995.**

171. Sharma J D, Jain P and Sohu D, Quality Status of groundwater of Sanganer tehsil in Jaipur district. Nature Env Polln Techno, 4(2), 207–212, **2005.**

172. Sharma S K, Tiwari A N and Nawale V P, Nitrate Pollution in Ground water of Nagpur city area. Proc Nati Conf Polln Prev Contl India : IAEM, 2 – 3 March 2002, Nagpur, 173–176, **2002.**

173. Shivasharanappa S P and Mallikarjun H S, Assessment of ground water quality characteristics and Water Quality Index (WQI) of Bidar city and its industrial area, Karnataka State, India", International J. of Environ. sciences, 2(2), 965-976, **2011.**

174. Shrivastava N and Tyagi A, Study of physicochemical Characteristics of waterbodies around Jaipur, J. Environ. Bio., 24 (2), 177–180, **2003.**

175. Shrivastava S, Verma K, Das T B and Das R, Removal of zinc from wastewater by adsorption on flyash. Ind. J. Env Prot., 27 (6), 502 – 508, **2007.**

176. Shrivastava V S and Patil P R, Tapti river water pollution by industrial wastes: A statistical approach. Nat. Environ. Pollut. Tech., 1(3), 279-283, **2002.**

177. Shyamala R, Shanthi M and Lalitha P, Physicochemical Analysis of Bore well Water Samples of Telungupalayam Area in Coimbatore District, Tamilnadu, India, Elect. J Chem. 5(4): 924-929, **2009.**

178. Singaraja C, Chidambaram S, Anandhan P, Prasanna M V, Thivya C, Thilagavathi R and Sarathidasan J, Geochemical Evaluation of Fluoride Contamination of Groundwater in the Thoothukudi District of Tamilnadu, India. Applied Water Science, 4, 241-250, **2014.**

179. Singh A and Choudhary S K, Chemical Analysis of Groundwater of Nathnagar Block under Bhagalpur District, Bihar (India)". J. of Environ. Science and Engineering, 53(1), 469-474, **2011.**

180. Singh A K, Raj B, Tiwari A K and Mahato M K, Evaluation of hydrogeochemical processes and groundwater quality in the Jhansi district of Bundelkhand region, India, Environ. Earth Sciences, 70(3), 1225-1247, **2013.**

181. Singh A K, Tewary B K and Sinha A, Hydrochemistry and Quality Assessment of Groundwater in Part of NOIDA Metropolitan City, Uttar Pradesh, J. Geological Society of India, 78, 523-540, **2011.**

182. Singh K P, Environ. effects of industrialization of groundwater resources: A case study of Ludhaina area, Punjab, India, Proc, Int. Sym. on Soil, geology and landform-impact of land uses in developing countries, Bangkok. E6. 1-E, 6-7, **1982.**

183. Singh M, Kaur S and Sooch S S, Groundwater pollution – An overview. J. IPHE., 2, 29-31, **2003.**

184. Singh P K, Tiwari A K and Mahato M K, Qualitative Assessment of Surface Water of West Bokaro Coalfield, Jharkhand by Using Water Quality Index Method, International J. of ChemTech Research, 5(5), **2013.**

185. Singh P K, Tiwari A K, Painigarhy B P and Mahato M K, Water quality indices used for water resources vulnerability assessment using GIS technique, a review, International J. of Earth Science and Engineering, 6(6-1), 1594-1600, **2013.**

186. Singh V, Physico-chemical examination of water, sewage and Industrial effluents, Res.J.Chem.and E nv. 10(3), 62-66, **2006.**

187. Sinha D K and Saxena R Statistical Assessment of Underground Drinking Water Contamination and Effect of Monsoon at Hasanpur,

J.P. Nagar (Uttar Pradesh, India). J. Environ. Sci. Eng. 48(3), 157-164, **2006.**

188. Somashekar R K, Rameshaiah V and Chethana Suvarna A, Groundwater chemistry of Channapatna Taluk (Bangalore rural district) – Regression and cluster analysis. J. Environ. Pollut., 7(2), 101-109, **2000.**

189. Spalding R and Exner M, Occurrence of nitrate in groundwater: A review. J. Environ. Qual., 22, 392-402, **1993.**

190. Srivasthava A K and Sinha D K, Ind. J. of Environ. protection, 14(5), 30-345, **1994.**

191. Standards methods for Examination of Water and Wastewater. American Public Health Association, American Water Work Association and Water Pollution Control Federation, 22nd, Washington, DC, **2012.**

192. Stigter T Y, Ribeiro L, and Carvalho Dill A M M, Application of a groundwater quality index as an assessment and communication tool in agro environ. Policies–Two Portuguese case studies, J. of Hydrology, 327, 578–591, **2006a.**

193. Subba Rao C and Subba Rao N V, Groundwater quality in a residential colony. Ind. J. Environ. Hlth., 37(4), 295-300, **1995.**

194. Subba Rao M V, Rao V D and Andrews B S A, Assessment of Quality of Drinking Water at Srikurmam in Srikakulam District, Andhra Pradesh, India," International Research J. of Environ. Science, 1(2), 13-20, **2012.**

195. Subba Rao N, Assessment of groundwater conditions in parts of Guntur district, Andhra Pradesh, India. UGC Minor Research Project Report, **1995.**

196. Subba Rao N, Environ. impact of industrial effluents in ground water regions of Visakhapatnam Industrial Complex. Ind. J. of Geology 65, 35–43, **1993.**

197. Subin M P, Anitha C T and Sidhimol P D, The study of water Quality of Tripunithura, a city suburb of Ernakulam District in Kerala, India. 10(4), 583-588, **2011.**

198. Suma Latha S, Ambika S R A and Prasad S J, Fluoride concentration status of groundwater in Karnataka, India. Current Sci. 76, 730–734, **1999.**

199. Suryanarayana K, Effect of groundwater quality on health hazards in parts of eastern ghats. Ind. J. Environ. Protec., 15(7), 497-500, **1995.**

200. Tagy S, Sharma B, Singh P and Dhobal R, Water Quality Assessment in terms of Water Quality Index, American J. of Water Resources, 1(3), 34-38, **2013.**

201. Tatawat R K and Chandel P S, Quality of ground water of Jaipur city, Rajasthan (India) and its suitability for domestic and irrigation purpose" Applied Ecology and Environ. Research, 6(2), 79-88, **2007.**

202. Tewari A, Dubey A, and Trivedi A, A study on physico-chemical characteristics of ground water quality. J Chem Phar Res. 2(2), 510-518, **2010.**

203. Tiwari A K and Singh A K, Hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh, J. Geological Society India, 83(3), 329-343, **2014.**

204. Tiwari T N and Mishra M A, A preliminary assignment of water quality index of major Ind. rivers. Ind. J. Environ. Protection, 5, 276-279, **1985.**

205. Todd D K, Groundwater hydrology. John Wiley and Sons, New York (1995). Vates, M.V.: Septic tank density and groundwater contamination, Groundwater, 23(5), 586-590, **1986.**

206. Tripathi I P and Singh R, Fluoride distribution in ground water at the around Chitrakoot, Ind. J. Environ. Prot. 16, 805-807, **1996.**

207. Trivedy R K and Goel P K, chemical and Biological Methods for pollution studies; Environ. Publications ,Karad ,India, **1986.**

208. Vasanthavigar M and Vasudevan S, Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin,

Tamilnadu, India, Environ. monitoring and assessment, 171(1-4), 595-609, **2010.**

209. Venkateswara Rao S, Krishna Rao G and Subba Rao N, Factors controlling groundwater quality in parts of Srikakulam District, Andhra Pradesh, India. J. Ind. Acad. Geosci. 39, 33–39, **1996.**

210. Verma N K, Jain O P and P K, Shrivastava, Preliminary studies on heavy metals in ground water of Mandeep by Atomic Adsorption spectroscopy Proc, Acad, Environ. Biology, 4(1):123-126, **1995.**

211. Verma S, Mukherjee A, Choudhury R and Mahanta C, Brahmaputra River Basin Groundwater: Solute Distribution, Chemical Evolution and Arsenic Occurrences in Different Geomorphic Settings. J. of Hydrology, Regional Studies, 4, 131-153, **2015.**

212. Vishnoi S R and Srivastava P N, Seasonal pollution assessment through comparative hydro biological studied in river Jojari at Salawas, Jodhpur. Ind. J. Environ Sci., 9(1) 33-34, **2005.**

213. Wabaluti Rambai, Dissertation Phase-1, Evaluation of water quality index and computation of Environ. health indicators-case study, S.G.S.I.T.S. Indore, **2013.**

214. Westcot D W and Ayers R C, Water quality criteria in Irrigation with Reclaim municipal wastewater: A guidance resources control board sacramento, California, **1984.**

215. WHO, "Guidelines for drinking water quality", Geneva, World Health Organization, **2004.**

216. WHO, International Standards for Drinking Water, World Health Organization, Geneva, **1971.**

217. Wilcox L V, Classification and use of irrigation waters. USDA Crc. 969. Washington D.C., 19, **1955.**

218. Yadav J P and Lata S, Fluoride levels in drinking water sources in rural areas of block Jhajjar, district Jhajjar, Haryana, J. Ind. Water Works Association, 131-136, **2004.**

219. Yadav S S and Kumar R, Contamination of fluoride content in ground water of Rampur city, Uttar Pradesh, India.J.Ultra chem., 6(2),181-186, **2010.**

220. Zafar A R, Limnology of Hussain Sagar lake, Hyderbad. Phykos., 5, 115-126, **1966.**

ANEXURES - 1

GLOBAL WATER DISTRIBUTION

Water Source	Volume ($1000\ km^3$)	% of Total Water	% of Fresh Water
Oceans, Sea and Bays	1,338,000	96.5	-
Ice caps, Glaciers and permanent Snow	24,064	1.74	68.7
Groundwater	23,400	1.7	-
Fresh	10,530	0.76	30.1
Saline	12,870	0.94	-
Soil Moisture	16.5	0.001	0.05
Ground Ice and Permafrost	300	0.022	0.86
Lakes	176.4	0.013	-
Fresh	91.0	0.007	0.26
Saline	85.4	0.006	-
Atmosphere	12.9	0.001	0.04
Swamp water	11.47	0.0008	0.03
Rivers	2.12	0.0002	0.006
Biological water	1.12	0.0001	0.003
Total	1,385,984	100.0	100.0

NATIONAL AND INTERNATIONAL STANDARDS OF DRINKING WATER

S. No.	Parameters	Ind. Standards BIS 10500 (1991)		W.H.O. (1971)		International Standards (APHA1993)	
		Maximum Acceptable concentration	Maximum Allowable concentration	Maximum Acceptable concentration	Maximum Allowable concentration	Maximum Acceptable concentration	Maximum Allowable concentration
1	**Color**	5 Units	25 Units	5 Units	25 Units	5 Units	25 Units
2	**Odor**	Unobjectionable	~	Unobjectionable	~	Unobjectionable	~
3	**Taste**	Agreeable	~	Agreeable	~	Agreeable	~
4	**Turbidity**	5 NTU	10 NTU	2.5 NTU	10 NTU	2.5 NTU	10 NTU
5	**pH**	6.5 to 8.5	~	7.0 to 8.0	6.5 to 9.2	7.0 to 8.5	6.5 to 9.2
6	**TDS**	500	2000	500	1500	500	1500
7	**Total Alkalinity**	200	600				
8	**Total Hardness**	300	600	100	500	100	500
9	**Calcium**	75	200	75	200	75	200
10	**Magnesium**	30	150	80	150	30	150
11	**Chloride**	250	1000	200	600	200	600
12	**Sulphate**	200	400	200	400	200	400
13	**Nitrate**	45	100	45	~	45	100
14	**Fluoride**	1.0	1.5	0.9	1.7	0.7	1.5
15	**Iron**	0.3	1.0	0.1	1.0	0.1	1.0
16	**Zinc**	5.0	15	5.0	1.5	5.0	1.5
17	**Copper**	0.05	1.5	0.05	1.5	0.05	1.5
18	**Lead**	0.05	No Relaxation	~	0.1	0.1	No Relaxation
19	**Chromium**	0.05	No Relaxation				
20	**Manganese**	0.1	0.3				
21	**Arsenic**	0.05	No Relaxation	~	~	0.05	No Relaxation
22	**Cadmium**	0.01	No Relaxation	~	0.01	0.01	No Relaxation
23	**Cyanide**	0.05	No Relaxation	~	~	0.05	No Relaxation
24	**Mercury**	0.001	No Relaxation	~	~	0.001	No Relaxation
25	**Selenium**	0.01	No Relaxation	~	~	0.01	No Relaxation

ANEXURES – 3

COCENTRATION OF FLUORIDE IN DRINKING WATER AND ITS EFFECT ON HUMAN HEALTH

Fluoride Concentration (mg/L)	**Effect**
Nil	Adverse effect on pregnancy power and can be damage a fetus
< 0.5	Dental caries
0.5 – 1.5	Promotes dental health, prevents tooth decay
1.5 – 4.0	Dental fluorosis
4.0 – 10.0	Dental fluorosis, skeletal fluorosis severe pain in joints, back bones and other disorders.
> 10.0	Crippling fluorosis

ANEXURES – 4

INTERPRETATION OF LANGELIER SATURATION INDEX (LSI) TEST RESULT

Index	Appearance	Water condition Quality Issues
- 4.00	Very Severe Corrosion	Conditioning required
- 3.00	Severe Corrosion	Conditioning usually recommended
-2.00	Moderate Corrosion	Some conditioning is recommended
-1.00	Mild Corrosion	Need some conditioning
-0.50	Slight Corrosion	Should not / may need some conditioning
0.00	Balanced	Conditioning usually not recommended
0.50	Faint Scale Coating	Conditioning usually not recommended
1.00	Slight Scale / Encrustation	Some visual appearance concerns
2.00	Mild Scale / Encrustation	Should consider some conditioning
3.00	Moderate Scale / Encrustation	Should use some conditioning
4.00	Severe Scale / Encrustation	Conditioning usually required

CLASSIFICATION OF IRRIGATION WATER AS PER WILCOX (1948)

S. No.	**Parameters**	**Class**	**Limit**
1	**% Sodium**	Excellent	< 20
		Good	20 – 40
		Permissible	40 – 60
		Doubtful	60 – 80
		Unsuitable	> 80
2	**Electrical Conductance (µS/cm)**	Excellent	< 250
		Good	250 – 750
		Permissible	750 – 2250
		Doubtful	2250 – 3000
		Unsuitable	> 3000

ANEXURES – 6

CLLASSIFICATION OF IRRIGATION WATER AS PER RICHARD (1954)

S. No.	Problem	Parameters	Class	Limit
1	**Salinity Hazard**	**Electrical Conductance (µS/cm)**	Low (C_1)	100 – 250
			Medium (C_2)	250 – 750
			High (C_3)	750 – 2250
			Very High (C_4)	2250 – 5000
2	**Sodium (Alkali) Hazard**	**Sodium Adsorption Ratio (SAR)**	Low (S_1)	0 – 10
			Medium (S_2)	10 – 18
			High (S_3)	18 – 26
			Very High (S_4)	> 26

CLASSIFICATION OF IRRGATION WATER AS PER WESTCOT AND AYERS (1984)

S. No.	Problem	Parameters	Class	Limit
1	**Salinity (Affect the availability of crop water)**	**Electrical Conductance (dS/cm) / Total Dissolved Solids (mg / L)**	None	< 0.70 < 450
			Slight to Moderate	0.70 – 3.0 / 450 -2000
			Severe	> 3.0 / > 2000
2	**Specific ion toxicity (Affect the sensitivity of the crop)**	**Sodium Adsorption Ratio (SAR)**	None	< 3.0
			Slight to Moderate	3.0 – 9.0
			severe	> 9.0
3	**Permeability (Affect the infiltration rate of water in to soil)**	**Sodium Adsorption Ratio (SAR) / Electrical Conductance (dS / cm)**	None	0 – 3 / > 0.7 3 – 6 / > 1.2 6 – 12 / > 1.9 12 – 20 / > 2.9
			Slight to Moderate	0 – 3 / 0.7 – 0.2 3 – 6 / 1.2 – 0.3 6 – 12 / 1.9 – 0.5 12 – 20 / 2.9 – 0.3
			Severe	0 – 3 / < 0.2 3 – 6 / < 0.3 6 – 12 / < 0.5 12 – 20 / < 1.3

ANEXURES – 8

ABBREVIATIONS USED

S. No.	ABBREVIATION	DESCRIPTION
1	TDS	Total Dissolved Solids
2	DO	Dissolved Oxygen
3	BOD	Biological Oxygen Demand
4	COD	Chemical Oxygen Demand
5	SAR	Sodium Adsorption Ratio
6	AI	Aggressive Index
7	LSI	Langelier Saturation Index
8	RI	Ryzner Index
9	ESP	Exchangeable Sodium Percentage
10	RSC	Residual Sodium Carbonate

RESEARCH PAPERS PUBLISHED

1. Paper entitled **"ASSESSING VARIATION IN PHYSICOCHEMICAL CHARACTERISTICS OF GROUNDWATER OF DIGOD TEHSIL OF KOTA DISTRICT OF RAJASTHAN, INDIA, USING STATISTICAL CORRELATION STUDY"** published in **e-J. (Chemical Science Transaction)**, vol 3(4), pp 1502 – 1503, **2014.**

2. Paper entitled **"ASSESSMENT OF SEASONAL TRENDS IN GROUNDWATER QUALITY ACROSS THE ITAWA TEHSIL OF KOTA DISTRICT OF RAJASTHAN, INDIA"** published in **International J. of Current Research**, vol 7, pp 24138-24142, **2015.**

PARTICIPACTION IN
SEMINARS/ SYMPOSIUM/ CONFERENCES/

1. Presented Poster in 'National symposium on recent advances in chemical science" **(NSRACS – 2011)** on January 7 – 8, 2011 organized by Department of Pure and Applied Chemistry, University of Kota, Kota (Raj).

2. Actively participated in a **"3rd International River Festival"** held at Narmada Tawa Sangam, Bandra Bhan, Hoshangabad district, M.P. on February, 8 – 10, 2013.

3. Presented research paper and poster in "**National conference** on global Environ. changes and disaster management for sustainable life on Earth–A burning issue" held at Maharishi Arvind college of Engineering and Technology, Ranpur, Kota, Raj. on October 21st, 2013.

4. Presented research paper in "3rd **International Conference on Advance Trends in Engineering, Technology and Research" (ICATETR – 2014)** held at Bal Krishna Institute of Technology, Ranpur, Kota, Raj. on December 22 – 24, 2014.

SUMMARY

This thesis consists of four chapters as follows:

Chapter I: Introduction and Review of Literature

This chapter includes an introduction of the subject of the research, an idea about the study area, water quality and the factors that may affect the water quality or may pollute water. Groundwater is one of the natural sources for various purposes for the majority of the population of Kota district specifically village area. Quality of groundwater decides its suitability for drinking, domestic use, industrial use or for cleaning and other uses according to standards set by authentic agencies. Groundwater said to be polluted for various use when it contains enough impurities to make it unfit. The chapter also includes review of literature and scope of the work. Literature survey reveals that no specific work has been carried out till date to assess the quality of groundwater for drinking, irrigation and domestic purpose of Kota District hence present work has been initiated to indicate water quality status of the area.

Chapter II: Methods and Methodology

This part contains a systematic methodology i.e. details of sampling sites, methods of sampling standard scientific methods used for analysis and methods adopted for computation of important indices viz. LSI, RI, AI, PI, % Na, SAR, ESP and RSC. Groundwater samples were taken to analyse various physicochemical parameters viz. pH, Conductivity, Total Dissolved Solids, Carbonate Alkalinity, Bicarbonate Alkalinity, Total Alkalinity, Calcium Hardness, Magnesium Hardness, Total Hardness, Sodium, Potassium, Sulphate,

Chloride, Nitrate, and Phosphate (APHA Standard methods for the Examination of Water and Wastewater, 17th Edition, Washington, D.C. 1989)

Groundwater samples were collected from five tehsils of Kota district. These five tehsils are Ladpura, Digod, Sangod, Ramganjmandi, and Itawa. Six villages from each tehsil were selected for sampling. Monitoring was done during the four season's pre-monsoon, post-monsoon spring and winter throughout Three Years (from April, 2011 to March 2014). The samples were collected as composite samples; at every village site, samples were collected from four different points and then mixed together i.e. from thirty villages samples were collected from one hundred twenty points. Samples were collected in good quality screw-capped polypropylene bottles of one liter capacity, labeled properly and analyzed in laboratory for various physicochemical parameters. Samples were protected from outside contamination and preserved in refrigerator at 4^0C. The physicochemical assessment of groundwater of the study area and computation of various indices have been carried out to indicate the current water quality status of groundwater of the area.

Chapter III: Observations and Results

A statistical summary of groundwater chemistry investigated from the areas of Kota district are presented in this chapter. This chapter contains all observations and results in tabular and graphical form with suitable statistical analysis of data obtained in three years. The sampling sites and water analysis data were associated for the generation of graph of selected water quality parameters. Obtained data were compared and correlated with standards given by WHO and

BIS to evaluate suitability for intended purpose e.g. domestic, drinking, industrial, and irrigation.

Pearson's Correlations coefficients are calculated among average values of various physicochemical parameters to find out the relationship among various parameters. LSI (Langelier Saturation Index), PI (Permeability Index), RI (Ryzner Index) and AI (Aggressive Index) reflect the suitability for industrial utility whereas % Na, SAR (Sodium Adsorption Ratio), ESP (Exchangeable Sodium Percentage) and RSC (Residual Sodium Carbonate) reveal suitability for the irrigation use.

Chapter IV: Discussion on findings

The present chapter includes the summaries that describe the factors affecting water quality and analysis of results. The physicochemical assessment of groundwater samples of five tehsils of Kota District was used to evaluate the suitability of groundwater for drinking, industrial and agricultural purpose. Groundwater contamination has become a major issue in the recent years. A sensitivity analysis showed that now a day's groundwater quality deteriorated. Groundwater source is considered the main water supply source for all kind of human usage in the villages of five tehsils of Kota district (domestic, agricultural and industrial). Based on observations few recommendations and suggestions were pointed out for sustainability of groundwater quality. Groundwater mostly contaminated due to the irresponsible attitude of the people of the area and population growth. However the quality of groundwater of Kota district is of moderate category.

Digod Tehsil:

From the observations, it can be concluded that the concentration of EC, TDS, TA, CO_3^{2-} , K^+, SO_4^{2-} and NO_3^- were within the permissible limit but nearly one third (1/3) of the studied samples (32%) were high in pH, HCO_3^-, Ca^{2+}, Mg^{2+} and F^- which suggest the poor water quality of these water samples.

Itawa Tehsil:

From the results, it may be defined that the values of TDS, TA, CO_3^{2-}, K^+, SO_4^{2-} and NO_3^- were within the permissible limit but nearly half the studied samples (48%) were high in pH, EC, HCO_3^-, Ca^{2+}, Mg^{2+}, Na^+, F^- which suggest the poor water quality of these water samples.

Ladpura Tehsil:

From the results it can be interpreted, that the values of pH, TDS, TA, CO_3^{2-} , HCO_3^-, K^+, SO_4^{2-} and NO_3^- were within permissible limits but nearly half of the studied samples (58%) were high in EC, TH, Na^+, Ca^{2+}, Mg^{2+} and F^- which suggest the poor water quality of these water samples.

Ramganjmandi Tehsil:

From the annotations, it can be drawn out the values of pH, EC, TDS, TA, CO_3^{2-} , HCO_3^-, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-} and NO_3^- were within permissible limits but nearly half of the studied samples (52%) were high in HCO_3^-, Na^+, Ca^{2+}, Mg^{2+} and F^- which suggest the poor water quality of these water samples.

Sangod Tehsil:

From the observation, it may easily be concluded that the concentration of pH, TDS, TA, CO_3^{2-}, K^+ and SO_4^{2-} were within the permissible limit but some of the

studied samples (29%) were high in EC, TH, HCO_3^-, Ca^{2+}, Mg^{2+}, NO_3^-, and F^- which suggest the poor water quality in these water samples.

Finally it can be drawn out that general characteristics of groundwater samples were unsuitable for household, irrigation, and commercial purpose during the study period. However, treatment can be suggested for high pH, EC, Na^+, Ca^{2+}, Mg^{2+}, HCO_3^-, F^- and NO_3^- values specifically.

A systematic and alphabetic bibliography and appendices are given in the end of thesis.

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 12, pp.24138-24142, December, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

ASSESSMENT OF SEASONAL TRENDS IN GROUNDWATER QUALITY ACROSS THE ITAWA TEHSIL OF KOTA DISTRICT OF RAJASTHAN, INDIA

***Anilesh Kumar Yadav, Nitin Gupta, S. M. Nafees, K. K. Gupta, and Kalpana, S.,**

Department of Chemistry, Govt. College Kota, Rajasthan, India

ARTICLE INFO

Article History:
Received 26th September, 2015
Received in revised form
24th October, 2015
Accepted 19th November, 2015
Published online 30th December, 2015

Key words:

WQI, Seasonal variation,
Groundwater pollution,
Itawa Tehsil,
Kota District.

ABSTRACT

To assess the impact of seasonal trends on groundwater quality, samples were collected during pre-monsoon, post-monsoon, spring and winter seasons from selected locations of Itawa tehsil of Kota District of Rajasthan state (India) from 2011 to 2013 and determined physicochemical parameters like pH, TDS, specific conductivity, total alkalinity, magnesium, nitrate, sulphate, phosphate, potassium, sodium, hardness, chloride, and fluoride. Standard research techniques were used to evaluate the quality of groundwater and its suitability for irrigation and drinking purpose. Results of investigation showed that conductivity, alkalinity and hardness parameters have higher values during the post-monsoon season than in the spring season. The average values for groundwater in pre-monsoon, post-monsoon, spring and winter seasons of the pH was 7.3 - 8.1, EC (Electrical Conductivity) 910 - 1313 µs/cm, TDS (Total Dissolved Solid) 659 - 911 mg/L, TA (Total Alkalinity) 205 - 407 mg/L, TH (Total Hardness) 120 - 312 mg /L, Ca (Calcium) 79 - 185 mg/L, Mg (Magnesium) 43 -125 mg/L, Na (Sodium) 109 - 183 mg/L, K (Potassium) 5 - 11 mg/L, Cl (Chloride) 54 - 107 mg/L, SO_4^{2-} (Sulphate) 64 - 125 mg/L, NO_3^- (Nitrate) 19 - 41 mg/L, PO_4^{3-} (Phosphate) 0.28 - 0.55 mg/L. The results were compared with the World Health Organization (WHO, 2006) guideline limits for drinking water[1]. The study suggested that the majority of the groundwater samples were unsuitable for irrigation in post-monsoon compared to that in pre-monsoon.

Citation: Anilesh Kumar Yadav, Nitin Gupta, S.M. Nafees, K. K. Gupta and Kalpana, S, 2015. "Assessment of Seasonal trends in groundwater quality across the Itawa Tehsil of Kota District of Rajasthan, India", *International Journal of Current Research,* 7, (12), ***24138-24142***.

INTRODUCTION

Groundwater is the precious source for irrigation and drinking purpose in rural and urban area communities. Along with natural process human activities generate an undesirable change in groundwater quality. In recent years degradation of groundwater quality is a major environmental issue of concern. Water is an essential substance for all living beings to survive on this planet. In India millions of people of rural and urban communities are dependent on groundwater for drinking and other purposes. Assessment of groundwater quality is very important to check the suitability of water for various purposes (Shrinivasa *et al.,* 2000). Groundwater is a most abundant ecological resource which situates below the land surfaces and withdrawn by people of urban and rural areas for different activities (Singh *et al.,* 2008). If human use upsets the balance between recharge, capture, and natural outflows, aquifer equilibrium lost until a new balance is reached.

****Corresponding author: Anilesh Kumar Yadav***
Department of Chemistry, Govt. College Kota, Rajasthan, India

The major anthropogenic activities responsible for degradation of groundwater quality are urbanization, industrialization, and agricultural practices (Hakim *et al.,* 2009). Physicochemical properties of Groundwater vary due to intense agriculture activities (use of fertilizers, insecticides, pesticides and lime), industrial waste (chemical waste, toxic waste and solid waste), improper handling of domestic waste, seasonal variation, high population density etc. (Sharma *et al.,* 2004). Most of the rural and urban populations have to depend on unsafe groundwater sources for their routine purpose (Reza *et al.,* 2009).

Chemical contamination of groundwater may pose serious health hazards. In order to understand the contamination level and effect of seasonal trends on physicochemical properties of groundwater, an intensive investigation was undertaken (Rajankar *et al.,* 2011). A huge number of studies have been carried out to estimate the suitability of groundwater for irrigation and drinking purpose in various parts of India and across the world. Earlier researches indicate that groundwater quality status varies due to climate change and seasonal variations (Sharma *et al.,* 1995; Subba 2002; Jha *et al.,* 2000; Sreedevi 2004; Jain *et al.,* 2010; Singh *et al.,* 1994;

Mittal *et al.,* 1994). People of Itawa tehsil of Kota District of Rajasthan state, India largely depend upon groundwater for drinking and irrigation purpose. Therefore, it is considered worthwhile to carry out systematic studies and report variations in quality of the groundwater of the selected area in different seasons by analysing different physicochemical characteristics of different water samples collected from the study area in four different seasons (pre-monsoon, post-monsoon, winter and spring).

MATERIAL AND METHODS

The Study Area

The tehsil of Itawa is in Kota District, which is in the Eastern part of Rajasthan state, India. In geographical terms, the location of the Kota District is 24º 25' and 25º 51' North latitude and 75º 31' and 77º 26' East longitude. The Kota District is situated on the banks of Chambal, one of the premier rivers in the nation.

The geography of Kota district is such that it is surrounded by Bundi and Tonk district in North, Sawai Madhopur in North West, Baran district in East, Jhalawar and Mandsor district of M.P. in South, and Chittorgarh district in West. The Kota district features a hot, semi–arid climate, with high temperature and mild winter. Kota district has several major power plants and industries. The range of annual temperature is 8^0C – 47^0C including yearly high and low temperatures in degrees Celsius. The average annual rainfall in the Kota district is about 660.6 mm. Kota is famous all over India for its coaching industry. In Itawa tehsil agriculture is the principal occupation of the people. The climatic conditions of Itawa tehsil are favorable for agricultural activities.

Collection of water samples

A systematic sampling was done for the physicochemical assessment of ground water quality of Itawa tehsil. Water samples were collected from 36 different sampling points of 6 village sites (Binayaka, Ayana, Ganeshganj, Rajopa,Talab and Dheepri Chambal) from both tube wells and hand pumps in spring, winter, pre-monsoon, and post monsoon, periods during years 2011 to 2013. The samples were collected as composite samples in clean and sterilised polythene bottles. Before sampling plastic bottles were rinsed with groundwater to be sampled. The samples were stored at a temperature below 4°C prior to analysis. A physicochemical analysis was carried out for 15 parameters viz. pH, conductivity, TDS (total dissolved solid), TH (total hardness), TA (total alkalinity), Bicarbonate Alkalinity and major ions K^+, Na^+, Ca^{+2}, Mg^{+2}, nitrate,

Table 1. Selected sampling sites in Itawa Tehsil

Sampling sites →	Binayaka		Ayana		Ganeshganj		Rajopa		Talab		Dheepri Chambal	
Sampling Time →	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening
Sample No. →	I-1	I-2	I-3	I-4	I-5	I-6	I-7	I-8	I-9	I-10	I-11	I-12

Table 2. Physicochemical Parameters obtained for Itawa Tehsil (average of values of different locations)

S. No.	Year	2011				2012				2013			
	Parameters/Season	pre	post	winter	spring	pre	post	winter	spring	pre	post	winter	spring
1	pH	7.8	7.3	7.6	7.7	8.0	7.5	7.7	7.9	8.1	7.6	7.8	8.0
2	Conductivity	1299	926	1105	1233	1303	935	1133	1309	1313	910	1141	1266
3	TDS (mg/L)	886	677	745	795	911	703	771	828	866	659	729	787
4	Total Alkalinity	400	213	303	367	402	217	317	380	407	205	321	383
5	Bicarbonate Alkalinity	400	213	303	367	402	217	317	380	407	205	321	383
6	Total Hardness	300	129	218	267	303	126	212	280	312	120	219	289
7	Calcium Hardness	178	80	131	159	181	80	125	168	185	79	134	172
8	Magnesium Hardness	120	53	86	107	121	51	86	111	125	43	84	115
9	Sodium	178	109	139	163	179	110	147	170	183	116	152	174
10	Potassium	9	5	7	8	11	6	9	10	11	6	8	10
11	Chloride	100	55	73	89	103	54	75	96	107	61	78	101
12	Sulphate	123	69	97	109	120	64	93	113	125	70	99	117
13	Nitrate	34	19	27	28	40	22	28	36	41	22	30	37
14	Fluoride	1.3	0.8	1.1	1.2	1.4	0.9	1.2	1.4	1.5	1.0	1.3	1.5
15	Phosphate	0.5	0.3	0.4	0.5	0.5	0.3	0.3	0.5	0.5	0.3	0.5	0.6

phosphate, sulphate, fluoride, chloride. Analytical grade reagents were used for the assessment of samples and double distilled water was used for preparation of solutions. This was to ensure that the samples collected truly representing the groundwater of the selected area.

RESULTS AND DISCUSSION

Physicochemical properties

To illustrate the groundwater quality of Itawa tehsil 15 different physicochemical parameters viz. pH, T.D.S (total

dissolved solid)., conductivity, TA (total alkalinity), bicarbonate alkalinity, TH (total hardness), levels of Cl^- (chloride), Mg^{2+} (magnesium), Ca^{+2} (calcium), NO_3^- (nitrate), SO_4^{2-} (sulphate), PO_4^{3-} (phosphate), Na^+ (sodium), K^+ (potassium) and F^- (fluoride) were determined of the groundwater samples collected from six selected sites viz. Binayaka, Ayana, Ganeshganj, Rajopa, Talab and Dheepri Chambal in four different seasons viz. pre-monsoon, post-monsoon, spring and winter of the years 2011, 2012 and 2013. The Physico-chemical parameters obtain for water samples collected in Itawa tehsil of Kota District are shown in Table 2.

Table 3. Results of different indices calculated with average values of physicochemical parameters obtained for different sampling locations

Year	2011				2012				2013			
Calculated Indices	pre	post	winter	spring	pre	post	winter	spring	pre	post	winter	spring
%Na	56.5	63.5	58.9	57.6	56.3	64.0	60.5	57.1	56.1	67.1	60.5	57.0
SAR	4.6	4.2	4.4	4.5	4.6	4.4	4.6	4.6	4.7	4.7	4.7	4.6
ESP	5.2	4.7	4.9	5.1	5.2	4.9	5.3	5.2	5.3	5.4	5.3	5.3
RSC	2.0	1.6	1.7	2.0	2.0	1.7	2.1	2.0	1.9	1.7	2.1	1.9

Table 4. Showing correlation analysis between various physicochemical parameters

	pH	TDS	TA	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-
pH	1	0.8035	0.8976	0.8933	0.9024	0.8758	0.9323	0.9555	0.9363	0.8957	0.9723	0.9859
TDS		1	0.9249	0.9241	0.9225	0.9325	0.9119	0.8861	0.9113	0.9089	0.8821	0.7850
TA			1	0.9973	0.9960	0.9949	0.9932	0.9352	0.9779	0.9907	0.9292	0.9110
TH				1	0.9992	0.9976	0.9907	0.9310	0.9829	0.9951	0.9341	0.9042
Ca^{2+}					1	0.9950	0.9923	0.9312	0.9869	0.9956	0.9389	0.9092
Mg^{2+}						1	0.9826	0.9290	0.9758	0.9883	0.9259	0.8875
Na^+							1	0.9467	0.9898	0.9909	0.9480	0.9399
K^+								1	0.9465	0.9195	0.9835	0.9546
Cl^-									1	0.9826	0.9603	0.9318
SO_4^{2-}										1	0.9305	0.9063
NO_3^-											1	0.9558
F^-												1

All parameters were compared with drinking water standards prescribed by BIS and WHO. Table 2 represents the average of the results of the physicochemical parameters of the samples (I-1, I-2, I-3, I-4, I-5, I-6, I-7, I-8, I-9, I-10, I-11, and I-12) of six sampling sites of Itawa tehsil. Classification of irrigation water on the basis of Na%, SAR, ESP and RSC is shown in Tables 3 and correlation matrix among 12 water quality parameters of groundwater of Itawa tehsil is shown in Table 4.

pH

pH values ranged between 7.3 and 8.1 during the study period (years 2011-2103). pH is a measurement of alkalinity of water in terms of hydrogen ion concentration. The results show that in the study period the maximum pH was recorded 8.1 in the pre-monsoon season of the year 2013 and the minimum pH was recorded 7.3 in post-monsoon season of the year 2011. The pH values were within the permissible limits as prescribed by WHO and BIS for all samples.

Electrical Conductivity (EC)

Electrical Conductivity values varied between 910 µS and 1313 µS. Electrical conductivity is the measurement of the ability of water to carry an electrical current. The maximum recorded EC 1313 was in the pre-monsoon season of the year 2013 and the minimum recorded EC was 910 in the post-monsoon season of the year 2013. Results show that conductance varies according to the season.

Total Dissolved Solids (TDS)

The value of total dissolved solids of groundwater ranged from 659 to 911 in the study period. Total dissolved solids denote weight of all solids that are dissolved in a given volume of water. The maximum value of total dissolved solids was examined in pre monsoon season of the year 2012 and minimum in post monsoon season of year 2013. Total dissolved solids of all the examined samples were within permissible limit of BIS (10500).

Total Alkalinity (TA)

Total alkalinity of groundwater samples ranged from 205 to 407 mg/L. Total alkalinity is the total concentration of bases in water. The maximum value of total alkalinity observed 407 mg/L in the pre-monsoon period of the year 2013 and the minimum value of total alkalinity observed 205 mg/L in the post-monsoon period of the year 2013. All samples have values within the permissible limit of drinking water standard BIS (10500).

Total Hardness (TH)

Total hardness values varied between 120 and 312 mg/L. The maximum value of total hardness was recorded 312 mg/L in the pre-monsoon period of the year 2013 and the minimum TH value was 120 mg/L recorded in post-monsoon season of the year 2013.

Calcium Hardness

The calcium hardness values ranged from 79 to 185 mg/L and these values were within permissible limits by WHO and BIS.

The maximum calcium value 185 mg/L was observed in pre-monsoon season of the year 2013 and the minimum value 79 mg/L was observed in post-monsoon season of the year 2013.

Magnesium Hardness

Inspection of the data Table 2 reveals that the magnesium values varied from 43 to 125 mg/L for all groundwater samples and these values were within the limits prescribed by BIS and WHO. The maximum magnesium value observed 125 mg/L in pre-monsoon season of the year 2013 and the minimum magnesium value was recorded 43 mg/L in post-monsoon season of the year 2013.

Sodium (Na^+)

The results recorded in Table 2 during study years show that amount of sodium ranged from 109 mg/L to 183 mg/L. In the year, 2013 the maximum value of sodium was recorded 183 mg/L in pre-monsoon and in the year 2011 minimum value of sodium was recorded 109 mg/L in post-monsoon.

Potassium (K^+)

The amount of potassium ranged from 5 mg/L to 11 mg/L. During Study Period the maximum value of potassium was recorded 11 mg/L in pre-monsoon season of the year 2013 and the minimum value of potassium was recorded 5 mg/L in post-monsoon season of the year 2011.

Chloride (Cl^-)

Chloride is found naturally in groundwater. Table 2 indicates that the chloride values extend from 54 mg/L to 107 mg/L. The maximum chloride values were recorded 107 mg/L in pre-monsoon season of the year 2013 and the minimum chloride values were recorded 54 mg/L in post-monsoon season of the year 2012.

Sulphate (SO_4^{2-})

The sulphate values displayed in Table 2 range from 64 mg/L to 125 mg/L. The observations recorded during study period 2011-2013, the maximum sulphate value was recorded 125 mg/L in pre-monsoon season of the year 2013 and the minimum sulphate value recorded 64 mg/L in post-monsoon season of the year 2012.

Nitrate (NO_3^-)

The data registered in the Table 2 for groundwater examined during the study years indicate that the nitrate values extend from 19 mg/L to 41 mg/ L. The observations showed that the maximum value of nitrate was recorded 41 mg/L in pre-monsoon season of the year 2013 and the minimum value of nitrate was recorded 19 mg/L in post-monsoon season of the year 2011.

Phosphate (PO_4^{3-})

During the years of investigations the quantity of phosphate has been found in range from 0.28 mg/L to 0.55 mg/L. During study period, the maximum phosphate value was recorded 0.55 mg/L in spring season of the year 2013 and the minimum phosphate value was recorded 0.28 mg/L in post-monsoon season of the year 2011.

Irrigation Water Quality

Evaluation of groundwater quality for irrigation was carried out calculating different indices like Na %, SAR, RSC, PI, AI and LSI. Statistics of water quality parameters of groundwater samples is presented in Table 3.

Sodium Percent (Na %)

Sodium percentage is used for adjudging the quality of water for agricultural purposes. The values of % Na varied from 39.9 to 43.5 (Table-3). According to Table-3 all the groundwater samples were within excellent to permissible limit for irrigation. Na% determined by using the following formula

$$Na\% = \frac{(Na^+ + K^+) \div (Ca^{2+} + Mg^{2+} + Na^+ + K^+)}{100}$$ (Concentrations are in meq/L).

Sodium Adsorption Ratio (SAR)

SAR is a measure of possible sodium hazard to crops. It is a most important parameter for the determination of suitability of water for irrigation. SAR values ranged from 2.4 to 3.3 (Table-3). The results show that all the samples were safe for irrigation point of view. SAR estimated by applying the following formula:

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+}+Mg^{2+}}{2}\right)}}$$ (Concentrations are in meq/L).

Residual sodium carbonate (RSC)

RSC is a significant parameter to determine the hazardous effect of carbonate and bicarbonate on quality of groundwater. RSC values ranged from 1 to 1.9 (Table 3). RSC was determined by the following equation:

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$ (Concentrations are in meq/L).

Exchangeable Sodium Percentage (ESP)

The calculated values of exchangeable sodium percentage (ESP) were ranged from 1.58 to 2.07. The maximum value calculated of ESP was in winter season of year 2013 and the minimum value was in post monsoon season of year 2011. It was calculated with the help of the following relationship:

$$ESP = \frac{100\ (-0.02126\ +\ 0.014575\ SAR)}{1 + (-0.0126\ +\ 0.01475\ SAR\ )}$$

Correlation coefficient analysis

Correlation is the relationship between two variables. To find out the relationship between two parameters x and y, the Karl Pearson's correlation coefficient, r is used and it is determined as follows –

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[\,n\sum x^2 - (\sum x)^2\,]\,[\,n\sum y^2 - (\sum y)^2\,]}}$$

Here, n = number of data points x = values of x–variable,y = values of y–variable.

In the present study highly positive correlations obtained between Total Hardness and Magnesium, (r = 0.997) and between Total alkalinity and Calcium Hardness (R=0.996). Strong correlation also revolved between Calcium and Total Hardness (0.999), magnesium and Total Hardness (0.997), sodium and sulphate (0.990), TDS and sulphate (0.908) TDS and sodium (0.911). A linear regression analysis is a very useful technique to estimate the predictable relationship between variables.

Conclusion

The groundwater quality analysis of the Itawa tehsil of Kota District was observed fit for drinking and irrigation purpose during most of seasons in other words the study period. In groundwater quality of Itawa tehsil is not harmful to people. Most of the physicochemical parameters were within permissible standard limits for drinking and other purposes.

Acknowledgments

The authors are thankful to the Principal, Govt. College, Kota and Head, P. G. Department of Chemistry Govt. College, Kota for providing necessary research facilities. The authors would also like to express sincere thanks to the members of the staff of the Environmental Chemistry Laboratory, for their active support during the course of the work.

REFERENCE

Hakim, M.A., Juraimi, A.S., Begum, M., Hasanuzzaman, M., Uddin, M.K. and Islam, M.M., 2009, Suitability evaluation of groundwater for irrigation, drinking and industrial purposes, *American Journal of Environmental Sciences*, 5(3), 413-419.

Indian Standards of Drinking Water, Specification (First Revision) IS-10500:1991 BIS, New Delhi, India.

Jain, C. K., Bandyopadhyay, A. and Bhadra, A., 2010, Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India, Environ Monit ssess., 166, 663-676.

Jha, A.N. and Verma, P.K., 2000. Physico–chemical property of drinking water in town area of Godda district under Santal Pargana, *Bihar, Poll Res.,* 19(2), 245–247.

Mittal, S.K., Rao, A. L., Singh, and Kumar, R., 1994, Groundwater Quality of some areas in Patiala city, *Indian J Environ Hlth,* 36; 51-53.

Rajankar, P.N., Tambekar, D.H., Wate, S.R. 2011. Seasonal Variation in Groundwater Quality of Yavatmal District, India, *E-Journal of Chemistry*, 8(2), 870-874.

Reza, R. and Singh, G., 2009. Physicochemical Analysis of Groudwater in Angul-Talcher Region of Orissa-India, Marsland Press, *Journal of American Science*, 5(5), 53-58.

Sharma, S. and R. Mathur, 1995, Seasonal changes in groundwater quality in Gwalior: health risk assessment, Poll. Res., 14(4); 373-376.

Sharma, S. K., Singh, V. and Chandel, C. P. S., 2004, Ground Water Pollution Problem and Evaluation of Physico-Chemical Properties of Ground Water, Environment and Ecology, 22 (spl-2), 319-324.

Shrinivasa Rao, B and Venkateshwaralu, P., 2000. Physicochemical Analysis of Selected Groundwater Samples, *Indian J. Environ Prot*., 20 (3), 161.

Singh, S.K. and Kumar P.S., 1994, Correlation of different physicochemical parameters of groundwater in Karimnagar district (Andhra Pradesh), *Cheml Environ Res*, 3 (1&2); 109- 116.

Singh, V. and Singh, U.C., 2008. Assessment of groundwater quality of parts of Gwalior (India) for agricultural purposes, *Indian Journal of Science and Technology*, 1(4), 15.

Sreedevi, P.D., 2004. Groundwater quality of Pageru river basin, Cuddapah district, Andhra Pradesh, *J Geol Soc India*, 64(5); 619–636.

Subba Rao, N., 2002. Geochemistry of groundwater in parts of Guntur district, Andhra Pradesh, India, Environ Geol, 41; 552–562.

WHO 2006. Guidelines for drinking water quality, 3rd ed. WHO, Geneva, Switzerland.

****