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Preliminary Findings on Comparative Study of Nitrogen Content In Groundwater of Agricultural Area Versus Non-Agricultural Areas In L. Gan Maldives

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Abstract: Nitrate contamination of groundwater is prevalent in areas with high agricultural activities. L. Gan is one of the islands in Maldives with a high level of farming. This study aims to determine the impact of agricultural activities on the ground waters of laamu atoll Gan. The objective of the study is to compare the amount of nitrate compounds in agricultural areas and non-agricultural areas by obtaining five water samples from wells of agricultural farm and another 5 water samples from non-agricultural, that is, household wells. One sample is collected from an isolated region to compare the water quality with agricultural farms and household wells. The nitrogen compounds that are being measured are nitrate, nitrite and ammonia using spectrophotometric analysis. The mean concentration of nitrate in agricultural and non-agricultural areas are 1.18 and 1.125 mg/L, respectively, with a mean difference of 0.055 mg/L, which is 4.8% higher nitrate concentration in agricultural areas than in non-agricultural areas. The nitrate concentration of the water sample obtained from an isolated area is 4.6 mg/L. For mean Nitrite concentration agricultural area has 0.056 mg/L, and the nonagricultural area has 0.0094 mg/L. the mean difference is 0.0464 mg/L of nitrite, which is 83 % higher nitrite concentration in agricultural areas than in non-agricultural areas. The water sample from the isolated area has a nitrite concentration of 0.033 mg/L. The ammonia concentration for agricultural non-agricultural is 0.526 and 0.26, respectively. The mean difference is 0.246 mg/L and which is 46% higher ammonia content in agricultural areas than in non-agricultural areas. The ammonia content in the isolated region water sample is 0.4 mg/L. This study indicates high nitrogen compounds in agricultural areas compared to non-agricultural areas. Over time the nitrate contamination may increase to a level that my pose health and environmental threats. Hence it is important to regulate the type and amount of fertilizer being used to prevent groundwater contamination.

Keywords: groundwater; Nitrate contamination; agricultural and non-agricultural areas

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1. INTRODUCTION

Groundwater makes up to 33% of all water withdrawals around the world, which is the water that is buried beneath the surface of the earth in aquifers of soil and permeable rock [1]. Over 2 billion people depend on groundwater for their everyday needs worldwide. Groundwater is essential to numerous industries, as well as too much of the world's agriculture and irrigation. Pollution of groundwater mostly impacts the poor in developing nations because They are unable to keep up with declining groundwater levels or to find another resource of water when their source is contaminated [2]. Maldives is one of the developing countries which depend on groundwater for both potables (used for drinking and cooking) and non-potable (used for bathing, washing, and flushing toilets) uses [3]. After rainfall, groundwater serves as the Maldives' secondary supply of fresh water [4]. During the dry season, there is a scarcity of drinking water in the outer islands of Maldives, and in some cases, poor people have to resort to drinking groundwater [3]. However, it is suspected that groundwater quality has declined in several islands due to factors such as contamination from agriculture. Agricultural practices increase nitrate and pesticide in groundwater. Nitrate leaching is a widespread problem in most agricultural areas, particularly where plants with high water and nitrogen demands tend to increase the amount of nitrate contamination on the ground waters [5]. Nitrogen compounds are transported into ground waters by water percolating below the root zones of agricultural fields. Nitrate contamination in groundwater has been reported to cause various health and environmental issues. This study aims to check the impacts of agricultural activities on level of nitrogen contamination of groundwater in L. Gan.

The aim of this study is to check the impact of agricultural activities on the groundwater quality of L.Gan by measuring concentrations of nitrogen compounds, specifically nitrate, nitrite and nitrogen ammonia. Other water quality parameters such as temperature, PH, alkalinity, conductivity, and total dissolved solids (TDS) are also measured to analyze groundwater quality. Observing the difference in nitrogen compounds in groundwater of agricultural areas and non-agricultural helps to understand the correlation between the use of fertilizers and the leaching of nitrogen compounds into groundwater and contaminating it.

The main objective of the study is to compare the concentration of nitrogen compounds in the groundwater of agricultural and non-agricultural areas of L atoll Gan Maldives. The objective is achieved by taking five groundwater samples from farm wells and another 5 groundwater samples from agricultural areas such as household wells and measuring the concentration of nitrogen compounds, specifically the concentration of nitrite nitrate and nitrogen ammonia, in each sample. One water sample is taken from an isolated region which is L. Gan Kulhi to observe a difference in water quality compared to agricultural sites and household wells.

The alternate hypothesis of the study is that the nitrogen content of groundwater in agricultural sites is higher than the content of nitrogen in non-agricultural sites. The null hypothesis would be that there is no statistical difference in nitrogen contents in the groundwater of agricultural sites and non-agricultural sites

2. LITERATURE REVIEW

Monitoring nitrogen based contamination of groundwaters due to agricultural practices have receive a considerable interest worldwide as farming has been identified as a cause of nitrogen (NO3-N) contamination in intensively farmed aquifers. Studies show that nitrate (NO3) levels in many aquifer systems beneath agriculture-dominated watersheds routinely exceed the permissible pollutant level (MCL) of 10 mg/l NO3-N[6]. Results of some field experiments have suggested that Nitrate leaching responds exponentially rather than linearly to increasing N inputs. [7].

The amount of leaching of nitrogen greatly depends on the climatic condition. High rainfall increases the rate of leaching of soil components into the ground waters. A study conducted by Libutti et al in 2017 showed the leached nitrogen content was higher in autumn-winter on average than in spring-summer [8]. In the autumn-winter season, high leaching of nitrogen is due to higher fertilization and high rainfall. Additional irrigation cause salt and nitrogen leaching in spring and summer. Climatic change estimation on leaching showed that swine manure application in spring has low leaching compared to fall application [9].

Another study by Jabloun et al in 2015 on the effect of nitrogen leaching on climatic factors such as temperature precipitation and crop management shows that the leaching of nitrogen has increased with increased precipitation and temperature. And the leaching is also dependent on location and cropping mechanisms [10].

A paper by Yadav, S. N. (1997), to estimate the leaching of NO3-N in groundwater from the root zone and non-root zone layer and analysis of a few management practices shows that 15% of applied N, 68% of residual NO3-N leached from non-root zone layer, and non20% of the residual NO3-N in the root zone layer are leached into groundwater. Also, for management practices, applying nitrogen in split doses had high nitrogen contamination in groundwater, while limited nitrogen use and tillage practices are associated with less nitrogen contamination of ground waters. Quantitative analysis of two tillage practices of chisel plow and no-till on groundwater contamination by nitrogen leaching shows that NO3-N concentrations of groundwater were higher in chisel plow system compared to the no-till practice[11].

2.1 Environmental and health effects of groundwater contamination with nitrogen

The introduction of nitrogen-based compounds in groundwater systems is linked with various environmental and health impacts. Increasing nitrate levels in the waters lead to algal blooms and the release of various toxins in groundwater bodies.

This may lead to numerous health issues, a reduction in the fertility of the soil, and salary for farmers[12]. It has been suggested that higher nitrate entering the human body through water, including groundwater, as a disease-causing factor. The most prevalent of them are adult digestive tract cancer and infant methemoglobinemia [13]. Furthermore, people who consumed water with high nitrate concentrations experienced thyroid gland enlargement, a rise in the prevalence of 15 different cancers, two different forms of birth abnormalities, and even hypertension. Additionally, high nitrate intake has been linked to an increase in the incidence of stomach cancer, according to reports Gao et al., 2012 [14]. In Maldives there is little to no data about how agricultural activities affect groundwater.

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2.2 L. Gan overview and its agricultural practices

Gan in Laamu atoll is the largest island in the Maldives, with a population of 4829 in 2022. [15].A road of 18 kilometers connects it to three nearby islands. The island is located 249.93 kilometers (155 miles; 135 nautical miles) south of Male' the capital of Maldives. Fishing and Agricultural activities have been the main source of the island's economy. Agricultural practices involve the growing of watermelons, cucumbers, pumpkins, eggplants, tomatoes and chilli plants. Among all plants, watermelon is the most commonly grown. Some of the farmers grow watermelon once a year during Ramadhan season, while some farmes grow all year long for a steady income. Agricultural practices are carried out in lands away from residential areas and on lands that have vegetation. According to island farmers, the preparation of farmland for plant growth involves removing pre-existing vegetation and tilling the selected regions of land and mixing it with fertilizers before sowing the seeds. The tilling is done up to 6 to 8 inches for watermelon, and it improves soil aeration and water holding capacity and aids easier root penetration. After sowing the seeds in the soil, the fertilizers are applied at least twice a week for about two and a half months till the fruit is harvested. Along with fertilizers, many pesticides and herbicides are also commonly applied to the crops. Since there is no strict regulation on the use of pesticides and fertilizers, the amount used by farmers varies greatly. In the first two months of crop growth, watering is done twice a day. During watering, nitrogen compounds in fertilizers leaching off from root zones into the groundwater. Since the Maldives is low laying island, there are high chances of leaching these chemicals into the ground water and contaminating it.

2.3 Sample parameters

Temperature is one of the most important water quality parameters that can affect the physical, chemical, and biological aspects of water. Temperature affects rates of chemical reactions taking place hence causing changes in organic and inorganic compounds in water[16]. the dissolved oxygen also decreases with an increase in temperature and affects organisms living in water bodies[17]. The temperature in a water body constantly changes depending on the climate and time of the day. During noon the temperature tends to get higher, and at night the temperature of th water decreases. Hence sample collection time has to be taken into consideration in evaluating water quality parameters.

Salinity level of water can be analyzed by two water quality parameters. These are conductivity (EC) and total dissolved solids (TDS). the correlation of these two parameters is often expressed by a simple equation TDS = k EC (in 25 0C). the k value increases with an increased amount of irons present in water. the relationship between TDS and conductivity is not directly proportional.

Conductivity is a measure of waters ability to conduct electricity. It is a parameter that gives information about ionic content in water. Conductivity level is subjective of a specific water body depending its bedrock. Some environments naturally have high conductivity level. Hence its essential to have a baseline for conductivity in different water bodies. The typical value for the conductivity of fresh groundwater is less than 150 µS/cm.Variation in conductivity level from baseline measurements can be used as an early sign of potential problem in a waterbody triggering further quality assessments.

Total dissolved Solids (TDS) is a measure of inorganic and organic solids dissolved in water. TDS can be measured by evaporating water from water samples and measuring a ass of remaining solids in a high precision scale. there are various sources of TDS in water including run off from road salts, chemicals and fertilizers from farms and soil clay particles in ground waters. Water that has a TDS level of more than 1000mg/L is unfit for consumption

PH of the water is a measure of the degree of acidity or alkalinity. The PH scale is logarithmic, meaning the change of PH by one factor changes the acidity or basicity tenfold. Water with PH below 7 is acidic, and water above 7 is considered basic. The PH of pure water is neutral. The PH of drinking water has to be between 6.5 to 8.5. The PH of the water is measured using a digital PH meter. PH can greatly influence other factors, such as temperature and biological components in water. Hence checking PH is important to determine water quality.

Alkalinity is the ability to resist changes in PH level or the buffering capacity of a solution. Alkalinity is measured as milligrams per litter of calcium carbonate. Since the changes in PH, directly and indirectly, affect water quality aspects, the buffering capacity of water is an essential property. Alkalinity is measured by the titration method.

2.4 Nitrogen and nitrogen compounds

Nitrogen is one of the most important plant nutrients. Nitrogen in the soil can come from animal and human waste, plant materials, external fertilizers or the air. Approximately 78 % of the earth's atmosphere consists if nitrogen gas. Nitrogen in the atmosphere enters into the soil by the nitrogen fixation process. Symbiotic and-symbiotic bacteria can directly convert atmospheric nitrogen into nitrates, a form in which plat can utilize the nitrogen. These Nitrogen can enter water bodies as inorganic nitrogen and ammonia. In addition to natural process intensive fertilizer application in agricultural farms have being associated with ground water contamination in many parts of the world. The indicators of groundwater contamination with nitrogen are nitrate, nitrite and ammonia.[18].

2.5 Water Quality Index

Water quality index a score representing a combination of factors which contribute in varying degrees . WQl represents the quality of the water and its applicability for different use cases. WQl are used by agencies and authorities which manage and distribute water as they are represented in a single number and can be used to relay information about the quality of water to the public [19]. WQl can tell us about the probability of presence of harmful substances and organisms. It can also tell us whether water from a supplier or a region is safe for applications such as cooking and drinking

3. METHODOLOGY

3.1 Sample Collection

Sample collection is done by emptying 500 ml PET bottles and rinsing the samples three times with the water samples to be collected. Sample collection time was in the evening at 4;00 pm. Samples were collected from different areas of L Gan covering most of the land area. Five samples were collected from agricultural sites where watermelon farming was practiced. Another five samples to represent non-agricultural areas were collected from household wells, and one sample was collected from an isolated region far from household and farm regions that are collected from the island Kulhi. Temperature readings were measured and noted during collection time. After collecting the samples in bottles, the bottles were clearly labelled, and the cap was tightly closed and taped to prevent any spillage during transportation. The water samples were then transferred to a cool box and kept at 4 °C. It is then transported to Male. to evaluate the nitrogen content amount of Nitrate, nitrite and nitrogen ammonia was conducted at Maldives Water and Sewerage Company (MWSC) laboratory. and parameters such as salinity, alkalinity, PH and Total dissolved Solids were conducted at MNU laboratory.

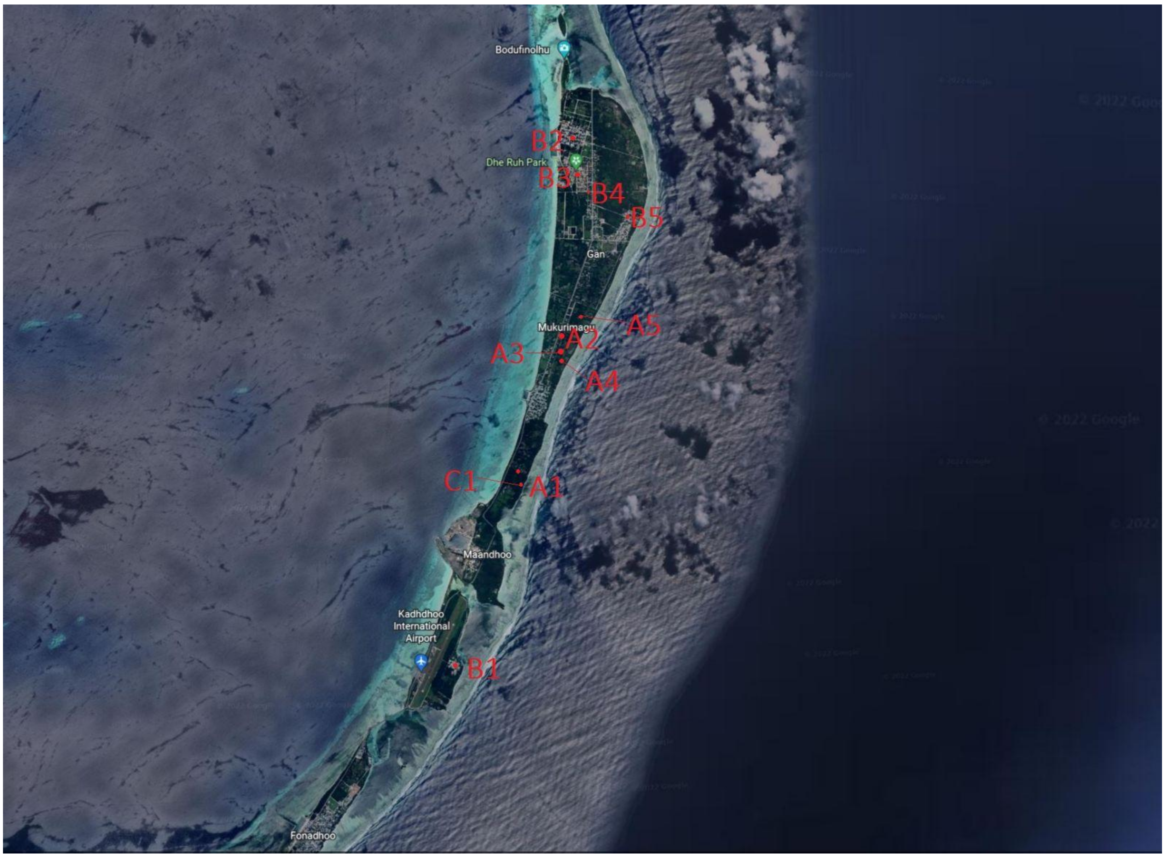

Figure 1.0 Location of each sample collected in L Gan. A represents agricultural areas, B non-agricultural regions households and C isolated regions kulhi.

3.2 Temperature

A digital thermometer was used to measure temperature, and the readings were taken during sample collection. The thermometer was rinsed with the water sample to be collected and then inserted into the water bottle. The water sample was slowly swirled to evenly distribute heat, and then the temperature readings were recorded

3.3 PH

The temperature of water samples was measured using a PH meter. The PH meter was first calibrated by using PH 7 and PH 10 buffer solutions. Distilled water was used to rinse the electrode of the PH meter and was allowed to dry. Water from each water sample bottle is poured into a 50 ml beaker and the electrode of the PH meter is inserted into the water samples. The PH reading on the Ph meter is recorded. After measuring the PH of one sample, the electrode of the PH meter is again rinsed with distilled water and the process is repeated for the rest of the samples.

3.4 Alkalinity

The titration method was used to measure the alkalinity of groundwater samples. Water samples were titrated against standard sulfuric acid. From each piece, 100ml of water was pipetted into the Erlenmeyer flask. Then few drops of phenolphthalein indicator are added. If the colour change of pink is observed, it has to be titrated with standard sulfuric acid until the pink colour turns colourless, which is the endpoint. The volume of acid required to reach the endpoint is recorded Since the colour remains colourless addition of phenolphthalein indicator, methyl orange, was added into the flask, and the colour change of yellow-orange colour was observed. The sample is then titrated against standard sulfuric acid in a burette. The acid was added at a faster rate initially until the point of water where the acid hits is constantly pink. Then acid was added drop by drop until a pinkish tint is observed. This is the endpoint of the titration, and when the endpoint is reached, the burette reading is recorded.

Titration is repeated three times for each water sample and the concordant values are used to take the mean titer value, which is used in calculations. To find methyl orange alkalinity due to calcium carbonate, the mean value of acid needed to neutralize water samples with methyl orange indicator is multiplied by 20. This process is repeated for all other water samples.

3.5 Salinity

- Conductivity

Conductivity is measured using a conductivity meter. It measures the flow of electricity of water between the electrodes. The conductivity meter is first calibrated before taking the reading of water samples. From each water sample

100 ml of water was transferred to a beaker, and the conductivity probe was inserted into the beaker for two minutes swishing it around lightly until the conductivity meter reading remained constant for 30 seconds. After measuring one water sample, the [probe has to be rinsed with deionized water before inserting it into another water sample. The process is repeated for 11 water samples to measure their conductivity.

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- Total dissolved Solids (TDS) by an evaporation method

First, 11 Petri dishes are obtained and labelled with the sample number. 5 samples of groundwater from agricultural regions as A1, A2, A3, A4 and A5. Another five samples, from non-agricultural areas, are from household wells a1 B2, B3 B4 and B5 and one sample is from an isolated place, C1. The labelled empty Petri dishes are weighed to the nearest 0.01 grams. A pipette is used to transfer 20 ml of water from each water sample to Petri dishes. The mass of Petri dishes with water is measured. The Petri dishes are then transferred tan an oven for drying and are kept for 24 hours at 80 °C. When all water is evaporated, the empty Petri dishes are weighed again, and the mass was recorded To obtain TDS for each water sample, the mass of Petri dishes after drying is subtracted from the mass of Petri dishes with water.

Calculate the salinity or TDS as (mg/dm3) mg of salt in 1 dm3/litre of the water sample. TDS can be given as mg/L or ppm. (1mg/L =1ppm).

3.6 Nitrite

Nitrite testing is done by the diazotization method and it is HACH method 8507. The reagent used is NitriVer® 3 Reagent Powder Pillows, 10 mL. For this procedure, water samples are allowed to reach room temperature. Sample preparation involves adding the water samples into the sample cell up to the 10 ml mark. The contents of one NitriVer 3 Reagent Powder Pillow were added to the sample cell. The mixture is swirled to ensure an even mixing of the reagent. A pink colour indicates the presence of nitrite in the sample, and the intensity of the colour is proportional to the concentration of nitrogen. The timer was started, and the reaction was allowed to occur for 20 minutes. The prepared sample is kept away from ultraviolet light as it can cause a colour change from pink to yellow.

For qualitative analysis of nitrite in the sample, the sample is run in a photo spectrometer with a wavelength of 507 nm. In the photo spectrometer, the program 371 N, Nitrite LR PP was selected. the concentration of nitrate corresponding to the absorbance value is displayed. In photo spectroscopic analysis, before analyzing the sample with the reagent, first, a blank sample is prepared by adding sample water to the 10 ml mark of the sample cell. This is then inserted into a cell holder, and the readings are shown in the display. The device is then zeroed, and the sample cell with NitriVer 3 Reagent Powder Pillow was then inserted into the holder to obtain nitrite concentration in mg/L.

3.7 Nitrate

To test for nitrates in ground water samples cadmium reduction method is used. It uses HACH method 8171. The reagents used for this method is NitraVer® Nitrate 5 Reagent and neoprene.

First, the samples in the bottles are allowed to reach to room temperature and PH to 7. The PH is adjusted to 7 by using a sodium hydroxide solution. the sample is prepared by filling the sample cell with 10 ml sample water and adding the reagent NitraVer® Nitrate to it.

Program 353 N, Nitrate MR PP is started and the 1 minute reaction time is started. The stopper is put on the sample and the sample is shaken vigorously for 1 minute. Some of the solid materials remains undissolved. The instrument timer is then set to 5 minutes. After the reaction has occurred of amber colour indicates presence of nitrates in the sample. the next step involves preparation of blank by filling a second sample cell with sample water from the stock solution. the sample cell is then cleaned and inserted into the sample holder, and the reading is observed. The instrument is then zeroed, and the display shows 0.0 mg/L counteracting any prior absorbance values. The prepared sample is then cleaned and inserted into the cell holder. This is done within two minutes after 5 minute reaction is allowed to take place. Pushing the read button will show the results in the display as mg/L of nitrates present in the water sample.

3.8 Ammonia

Nitrogen ammonia was measured using Nessler's method under HACH method. For this analysis program 380 N, Ammonia, Ness was started and sample preparation is began. To prepare the sample a mixing cylinder was filled with ground water sample up to 25 mL mark. The blank is then prepared by filling a mixing cylinder with deionized water up to 25 mL mark. To each of the mixing cylinder, the sample and the blank, three drops of mineral stabilizer is added. The stopper was placed in both the mixing cylinders and the mixing cylinders were inverted several times to ensure even mixing. Then dispersing agent polyvinyl alcohol was added to each of the mixing cylinder and the stopper were placed and mixing cylinders were inverted again several time for mixing of the reagents. 1.0 mL of Nessler Reagent is added to each of the mixing cylinder using pipette and the stopper were put in the mixing cylinders and the reagent was mixed by inverting the cylinders several times. The instrument timer of one-minute reaction was started. 10 ml of blank from the blank cylinder was poured in to a sample cell which is then cleaned and inserted into the sample holder. The zero button is then pressed showing 0.00 mg/L in the display. 10 mL sample water from sample cylinder is then poured into a sample cell ist-test cleaned and is inserted into cell holder and the result of nitrogen ammonia is obtained in mg/L by pressing the read button.

3.9 Statistical analysis methods

For statistical analysis of data obtained the means values of nitrogen-based compounds, nitrate, nitrite and ammonia in agricultural and non-agricultural areas are compared. And a significant test of students independent t-test is calculated from Microsoft excel to see a significant difference in the amount of nitrogen compounds in agricultural and non agricultural areas.

Water Quality Index was calculated to check the extent of pollution in each study site. Weighed arithmetic method was used to calculate Water Quality Index from Microsoft excel and the calculations are shown in figure 1 in appendix.

Results

Table 1 to Table 3 shows the physical appearance and nitrate nitrite and ammonia concentration values obtained for groundwater samples taken from agricultural nonagricultural and isolated regions. The results are obtained from MWSC laboratory, and the original file will be attached on the appendix.

Table 1. Nitrate nitrite and ammonia concentration in Agricultural farms of L.Gan.

Sample	Physical appearance	Nitrate	Nitrite	Nitrogen ammonia
A1	Clear with particles	2.500	0.211	0.22
A2	Clear with particles	0.600	0.025	0.27
A3	Pale yellow with particles	1.400	0.022	0.38
A4	Pale yellow with particles	0.900	0.015	1.62
A5	Clear with particles	0.500	0.006	0.14

Table 2. Nitrate nitrite and ammonia concentration in Non agricultural areas (household wells) of L.Gan.

Sample from house hold wells	**Physical appearance**	**Nitrate (mg/L)**	**Nitrite (mg/L)**	**Nitrogen ammonia (mg/L)**
B1	Clear with particles	0.100	0.002	0.02
B2	Clear with particles	5.700	0.008	0.06
B3	Pale yellow with particles	0.500	0.007	0.06
B4	Clear with particles	3.5	0.025	0.12
B5	Clear with particles	0.4	0.005	1.14

Table 3. Nitrate nitrite and ammonia concentration in an isolated region (Kulhi) of L.Gan

Sample	Physical appearance	Nitrate (mg/L)	Nitrite (mg/L)	Nitrogen ammonia (mg/L)
C1: Isolated place kulhi	Pale yellow with particles	4.6	0.033	0.4

Table 4 to Table 6 shows the comparison of specific nitrogen compounds in each sample of groundwater taken from agricultural and non-agricultural regions. Nitrite, Nitrate, and Nitrogen ammonia concentration are shown separately in each table to compare the mean concentrations in agricultural and nonagricultural areas. Also, student's independent t-test calculations for each parameter, nitrate, nitrite, and nitrogen ammonia, to see if there is a significant different of these compound in agricultural and non-agricultural areas.

Table 4 Nitrate concentration in agricultural and non agricultural regions

Sample	Nitrate in agricultural regions mg/L	Nitrate in Non agricultural regions mg/L
1	2.500	0.100
2	0.600	-
2	1.400	0.500
4	0.900	3.50
5	0.500	0.40
Mean	**1.18**	**1.14**

Table 5. Statistical analysis. Student-independent t-test for water samples assuming equal variances with 95% confidence limit for Ammonia concentrations

t-Test: Two-Sample Assuming Equal Variances	***Nitrate in agricultural regions mg/L***	***Nitrate in Non agricultural regions mg/L***
Mean	1.18	2.04
Variance	0.667	6.088
Observations	5	5
Pooled Variance	3.3775	
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.739896166	
P(T<=t) one-tail	0.240254845	
t Critical one-tail	1.859548038	
P(T<=t) two-tail	0.480509691	
t Critical two-tail	2.306004135	

Table 6. Nitrite concentration in agricultural and non agricultural regions

Sample	Nitrite in **agricultural regions** mg/L	Nitrite in **Non-agricultural regions** mg/L
1	0.211	0.002
2	0.025	0.008
2	0.022	0.007
4	0.015	0.025
5	0.006	0.005
Mean	**0.056**	**0.009**

Table 7. Statistical analysis. Student independent t test for water samples assuming equal variances with 95% confidence limit for Ammonia concentrations

t-Test: Two-Sample Assuming Equal Variances	***Nitrite in agricultural regions mg/L***	***Nitrite in Non-agricultural regions mg/L***
Mean	0.0558	0.0094
Variance	0.0075807	0.0000813
Observations	5	5
Pooled Variance	0.003831	
Hypothesized Mean Difference	0	
df	8	
t Stat	1.185309892	
P(T<=t) one-tail	0.134953579	
t Critical one-tail	1.859548038	
P(T<=t) two-tail	0.269907159	
t Critical two-tail	2.306004135	

Table 8 Ammonia concentration in agricultural and non-agricultural regions

Sample	Nitrogen ammonia in agricultural regions mg/L	Nitrogen ammonia in Non-agricultural regions mg/L
1	0.22	0.02
2	0.27	0.06
2	0.38	0.06
4	1.62	0.12
5	0.14	1.14
Mean	**0.53**	**0.28**

Table 9 Statistical analysis. Student independent t test for water samples assuming equal variances with 95% confidence limit for Ammonia concentrations

t-Test: Two-Sample Assuming Equal Variances	***Nitrogen ammonia in agricultural regions mg/L***	***Nitrogen ammonia in Non-agricultural regions mg/L***
Mean	0.526	0.28
Variance	0.38158	0.2324
Observations	5	5
Pooled Variance	0.30699	
Hypothesized Mean Difference	0	
df	8	
t Stat	0.702009512	
P(T<=t) one-tail	0.251291288	
t Critical one-tail	1.859548038	
P(T<=t) two-tail	0.502582577	
t Critical two-tail	2.306004135	

To evaluate the quality of groundwater in different regions of L. Gan, various other parameters were also measured. These parameters are temperature, PH, Alkalinity, Conductivity and Total dissolved Solid (TDS). Table 6 to Table 8 shows values of temperature, PH, Alkalinity due to CaCO3, Conductivity and TDS for agricultural areas, Non agricultural areas and isolated areas.

Table 10. Water quality parameters; Temperature, PH, alkalinity, conductivity, and total dissolved solids (TDS) for agricultural farm groundwaters

Sample	Temperature (°C)	PH	Alkalinity mg/L CaC03	Conductivity (uS/cm)	TDS (mg/L)
A1: Agricultural farm 1	28.1	7.50	338	813	500
A2: Agricultural fam 2	29.9	7.54	315	721	500
A3: Agricultural farm 3	27.5	7.71	251	473	-
A4: Agricultural farm 4	28.5	7.52	325	661	-
A5: Agricultural farm 5	28.5	7.51	355	796	100

Table 11. Water quality parameters; Temperature, PH, alkalinity, conductivity, and total dissolved solids (TDS) for agricultural farm groundwaters

Sample	Temperature (°C)	PH	Alkalinity	Conductivity	TDS
B1: Household well 1	29.5	7.16	29	596	-
B2: Household well 2	29.3	7.54	434	990	500
B3: Household well 3	29.2	7.64	331	583	1000
B4: Household well 4	28.8	7.60	450	846	0.0
5: Household well 5	27.3	7.61	353	665	0.0

Table 12. Water quality parameters; Temperature, PH, alkalinity, conductivity and total dissolved solids (TDS) for agricultural farm groundwaters

Sample	Temperature (°C)	PH	Alkalinity	Conductivity	TDS
C1: Isolated place kulhi	29.5	7.61	443	12570	9000

Table 9 shows the mean values of each water quality parameter calculated for Agricultural, Non-agricultural and isolated areas. These mean values are important to calculate the water quality index for 3 selected regions

Table 13. Mean values of water quality parameters for Agricultural, non-agricultural and isolated regions

Quality Parameters mean	**Agricultural**	**Non-agricultural**	**Isolated**
PH	7.56	7.51	7.61
Alkalinity mg/L CaC03	316.8	392	443
Conductivity (uS/cm)	692	726	12570
TDS (mg/L)	366.7	750	12570
Nitrite (mg/L)	1.18	2.04	4.6
Nitrate(mg/L)	0.056	0.0094	0.33
Nitrogen Ammonia (mg/L)	0.526	0.28	0.4

The water quality index is a tool to determine how polluted a water body is. It gives a numerical value that is calculated using at least 7 water quality parameters to classify water bodies. The table 5.0 shows the quality status of water bodies corresponding to a range of values of water quality index.

Table 14. Standard water quality index for classification of waters

Water Quality	Quality Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unfit for consumption

Table 5.1 to 5.3 shows Wi, Qi, and QiWi calculated for ground waters of agricultural, non-agricultural, and isolated areas.

Table 15. Water quality index Wi, Qi, and WiQi for ground waters of agricultural regions

Parameter	Wi	Qi	QiWi
pH	0.0215	37.333	0.8015
Alkalinity	0.0009	158.400	0.1445
Conductivity	0.0005	173.000	0.0789
TDS	0.0003	61.117	0.0186
Nitrate	0.0608	39.333	2.3925
Nitrite	0.0036	0.112	0.0004
Ammonia	0.9124	263.000	239.9571
Sum	1.0000		**243.393**

WQI= ΣQiWi/ΣWi

= 243.39/1.00

= 243.39

Table 16. Water quality index Wi, Qi, and WiQi for ground waters of Non-agricultural region

Parameter	Wi	Qi	QiWi
pH	0.0215	34.000	0.7299
Alkalinity	0.0009	196.000	0.1788
Conductivity	0.0005	181.500	0.0828
TDS	0.0003	125.000	0.0380
Nitrate	0.0608	68.000	4.1361
Nitrite	0.0036	0.019	0.0001

Ammonia	0.9124	140.000	127.7338
Sum	1.0000		**132.900**

WQI = ΣQi Wi / ΣWi

= 132.90/1.00

= 132.90

Table 17. Water quality index Wi, Qi, and WiQi for ground waters of the isolated region

Parameter	**Wi**	**Qi**	**QiWi**
pH	0.0215	40.667	0.8730
Alkalinity	0.0009	221.500	0.2021
Conductivity	0.0005	3142.500	1.4336
TDS	0.0003	2095.000	0.6371
Nitrate	0.0608	153.333	9.3266
Nitrite	0.0036	0.660	0.0024
Ammonia	0.9124	200.000	182.477
Sum	1.0000		**194.952**

WQI= ΣQiWi/ΣWi

= 194.19/1.00

= 194.19

Table 18. The water quality index calculated for agricultural, nonagricultural, and isolated areas.

Locations	**Water Quality Index**
Agricultural regions	243.39
Non-agricultural regions	132.90
Isolated regions	194.19

4. STATISTICAL ANALYSIS RESULTS

Statistical analysis of students' independent t-test calculated for nitrate in table 2.1, nitrite in table 3.1, and ammonia in table 4.1 using 5 water samples from the agricultural area and 5 water samples from the non-agricultural area gives the following results. For nitrate degree of freedom is 8, t value calculated is -0.74 with p value of 0.48. Nitrite concentration in samples taken from agricultural and non agricultural areas have degree of freedom 8 and t value of 1.19 and a *p* value of 0.26. For ammonium concentrations, the degree of freedom obtained is 8, t value calculate 0.70 with a p value of 0.5. *p* value less than 1 indicates there is some difference is nitrogen compounds in agricultural and non-agricultural areas. However most scientists believe the statistical significance of less than 0.05 to be significant to reject the null hypothesis [20]. The *P* values obtained for the concentration of nitrate nitrite and ammonia in these two study sites are less than 0.05. Hence the null hypothesis that states there is no significant difference between nitrogen compounds in agricultural and nonagricultural area is accepted for alpha 0.05.

5. DISCUSSION

Nitrogen contamination of groundwater due to the intensive use of fertilizers is a major environmental concern worldwide. The nitrogen compounds evaluated in this study are nitrate, nitrite, and ammonia to compare their concentrations in agricultural, non-agricultural, and isolated areas.

The mean concentration of nitrate in agricultural and non-agricultural areas are 1.18 and 1.125 mg/L, respectively, with a mean difference of 0.055 mg/L, which is 4.8% higher nitrate concentration in agricultural areas than in non-agricultural areas. The nitrate concentration of the water sample obtained from an isolated area is 4.6 mg/L. which is approximately four times higher mean nitrate concentration than in agricultural and non-agricultural regions. The maximum nitrate concentration among the three studies is in the isolated region kulhi. Since kulhi is a standing water body surrounded by many plants, the nitrate major plant nutrient from soil may accumulate in water over time. These three sites have nitrate concentrations within WHO standard limits for drinking water which is less than 10 mg/L.

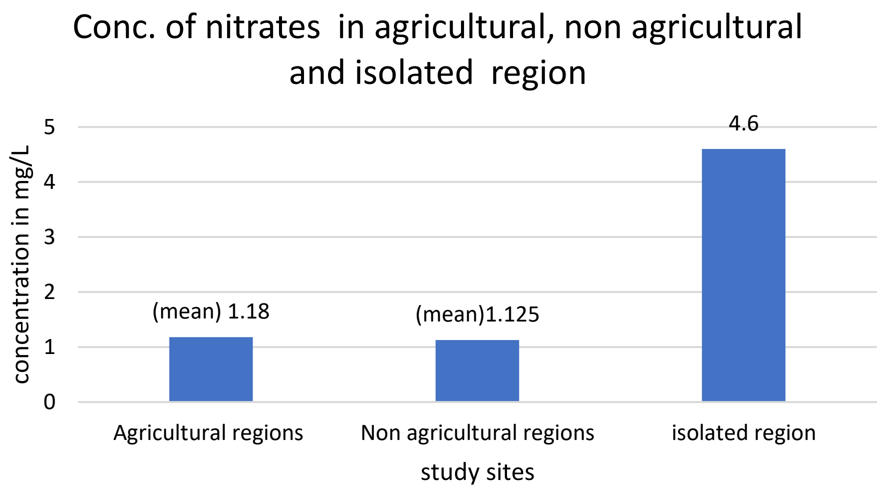

Figure 1. Shows the mean concentration of nitrates in the agricultural and non-agricultural area and the concentration of nitrate of water sample from isolated areas (kulhi)

The mean concentration of nitrite in an agricultural area is 0.056 mg/L, and for a nonagricultural area, it is 0.0094 mg/L. there is a mean difference of 0.0464 mg/L of nitrite, which is 83 % higher nitrite concentration in agricultural areas than in non-agricultural areas. The water sample from the isolated area has a nitrite concentration of 0.033 mg/L. That is 71% higher compared to the nonagricultural area. 41% less compared to the agricultural area. Nitrite iron is a pervasive intermediate in the nitrogen cycle in nature and usually does not occur in fertilizers. However, addition of ammonium compounds interconverts into nitrites which can then be converted to nitrates for plant used. High level of nitrate in waterbodies is an indication of nitrogen contamination in groundwater.

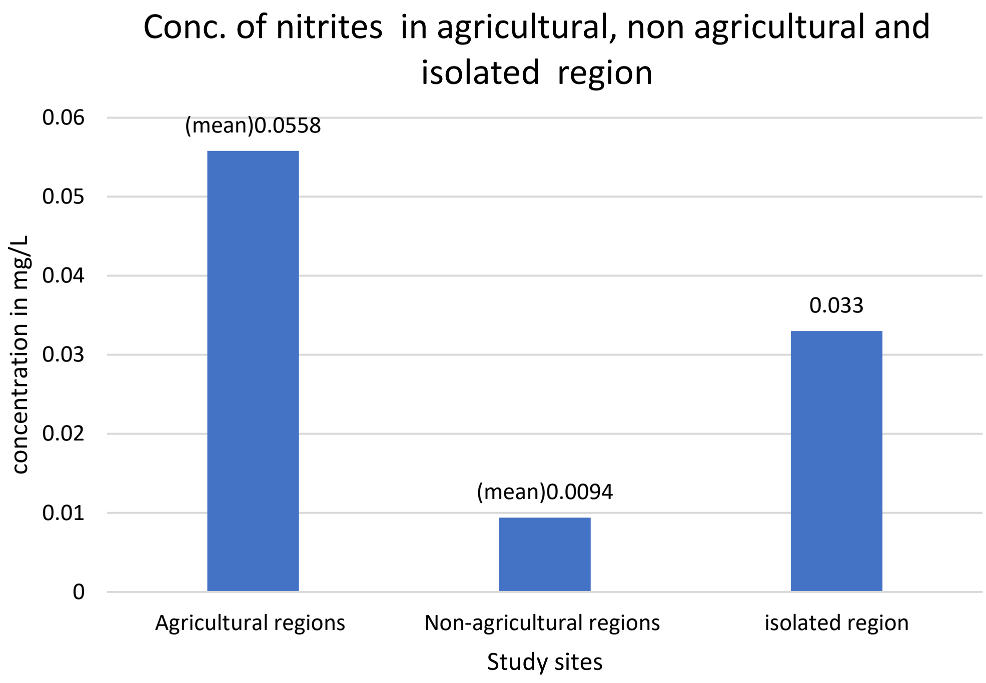

Figure 2. shows the mean concentration of nitrites in the agricultural and non-agricultural areas and the concentration of nitrite of water samples from isolated areas (kulhi)

The ammonia concentration for agricultural non-agricultural is 0.526 and 0.26, respectively. The mean difference is 0.246 mg/L and which is 46% higher ammonia content in agricultural areas than in non-agricultural areas. The ammonia content in the isolated region water sample is 0.4 mg/L.The highest concentration of ammonia in agricultural lands can be associated with the use of ammonia-based fertilizers in the form of ammonium salts. Also, ammonia can be produced by decomposition of nitrogen containing chemical in dead organic matter. The WHO standard for ammonia in drinking water is 0.2 mg/L. All of the three study sites have ammonia level above the recommended value and hence is not suitable for consumption.

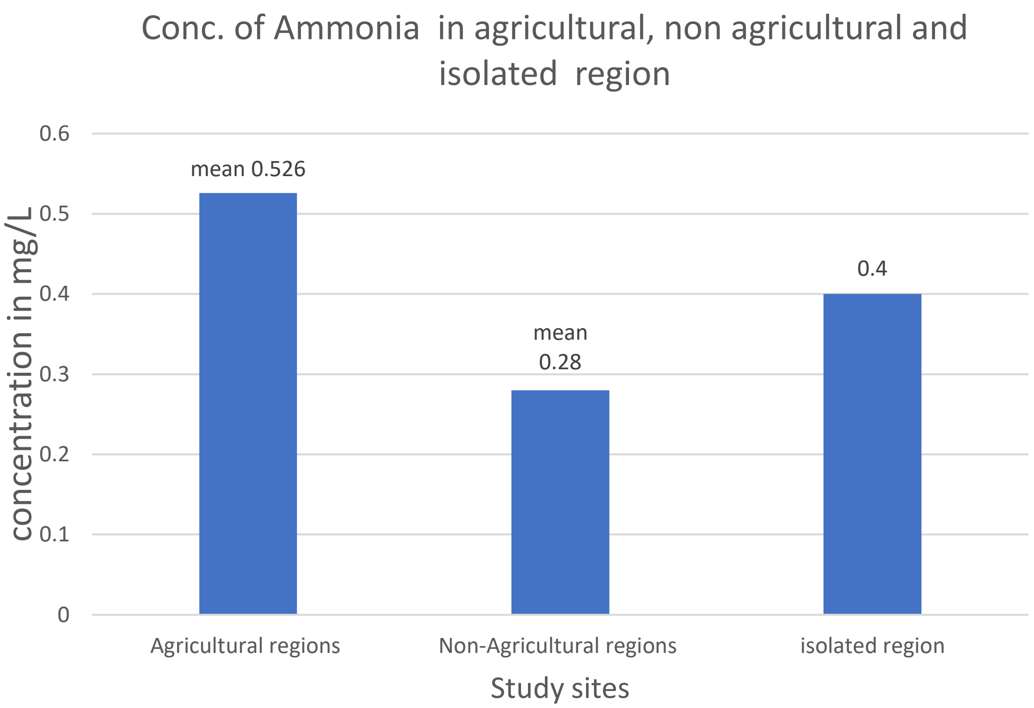

Figure 3. shows the mean concentration of ammonia in the agricultural and non-agricultural areas and the concentration of ammonia in water sample from isolated areas (kulhi)

The other parameters measured include temperature, PH, alkalinity, conductivity, and TDS to determine the water quality of groundwater in a different location. The highest level of all these parameters are found in a water sample obtained from an isolated region, kulhi. The exceptional level of conductivity and TDS may be due to the mixing of salt water during the tsunami in 2004. When comparing these parameters in agricultural and non-agricultural regions the mean PH was highest in an agricultural area with a PH of 7.56. the alkalinity (buffering capacity) conductivity and TDS are higher in non-agricultural area, with 392 mg/L of $CaCO_3$ for alkalinity, 720 (uS/cm) for conductivity and TDS of 750 mg/L.

5.1 Water Quality Index (WQI)

The water quality index is a tool to measure the extent of pollution of water bodies. It evaluates a single numerical value using mean values of all water quality parameters to represent a water body. A standard water quality index table in table 9.0 is used to classify groundwater. the water quality index calculated for the agricultural, non-agricultural and isolated region is 243, 133 and 194 respectively. All three sites have WQI greater than 100 and is unfit for consumption.

5.2 Limitations

There have been many limitations to this study. The soil profile and the cropping types and fertilizer application methods are important to understand the effect of leaching. The leaching of compounds from soil surface to groundwater has various contributing factors. One of the main factors is climate and for example rainfall increase rate of leaching by percolation of water from root zones of plants. Another major factor is the layer of soil above the ground. Maldives have the max average of 2.4 m of ground above sea level [21]. However, this figure may vary from place to place. The deeper the soil profile above ground water, less leaching would occur. The type and the amount of fertilizers or pesticides used may also increase the nitrogen leaching into ground water. The extent of irrigation and tilling practices are one of many factors that affect leaching of compounds. Soft textured soil would increase movements of compound down the soil profile, ultimately reaching to ground waters. Due to the limited time, those factors were not taken into consideration. Also, due to the shortage of budget less samples were used, which may not represent the whole study population.

In this investigation, household areas were considered as non-agricultural regions. This assumption may not be completely true since some households have plants like ornamental plants grown and treat them with fertilizers at times. Hence nitrate leaching due to these practices might not provide a significant difference in results in some places.

6. CONCLUSION

This investigation on comparing nitrate contamination of ground waters of agricultural and non-agricultural regions, five water samples collected from agricultural farms and five from non-agricultural household wells aims to determine impact of farming on quality of ground waters. The nitrogen compounds that are measured are nitrate nitrite and nitrogen ammonia by spectrophotometric analysis. The result indicates a higher level of nitrogen compounds in agricultural regions compared to non-agricultural regions. The impact may be mediated by intensive application of fertilizers by farmers. Even though the nitrogen compound levels in ground waters are not significant as of now, the nitrogen compounds may accumulate overtime and the contamination cannot be reversed. Hence it is essential to optimize the application of fertilizer and certain water management that may reduce ground water contamination. Also monitoring water quality parameters on regular basis would help to maintain the chemical, physical and biological integrity of the ground waters

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7. REFERENCE

[1] Famiglietti, J. S. (2014). The global groundwater crisis. Nature Climate Change, 4(11), Article 11. https://doi.org/10.1038/nclimate2425

[2] Kemper, K. E. (2004). Groundwater—From development to management. Hydrogeology Journal, 12(1), 3–5. https://doi.org/10.1007/s10040-003-0305-1

[3] Jaleel, M. I., Ibrahim, S. A., Hussain, A., Mustafa, M., & Pathirana, A. (2020). A Screening Approach for Assessing Groundwater Quality for Consumption in Small Islands: Case Study of 45 Inhabited Islands in the Maldives. Water, 12(8), Article 8. https://doi.org/10.3390/w12082209

[4] Deng, C., & Bailey, R. (2017). Assessing Groundwater Availability of the Maldives under Future Climate Conditions: Future Groundwater Availability of Maldives. Hydrological Processes, 31. https://doi.org/10.1002/hyp.11246

[5] Marouane, B., Belhsain, K., Jahdi, M., Hajjaji, S. E., Dahchour, A., & Dousset, S. (2014). Impact of agricultural practices on groundwater quality: Case of Gharb region-Morocco. 5.

[6] Almasri, M. N. (2007). Nitrate contamination of groundwater: A conceptual management framework. Environmental Impact Assessment Review, 27(3). https://doi.org/10.1016/j.eiar.2006.11.002

[7] Wang, Y., Ying, H., Yin, Y., Zheng, H., & Cui, Z. (2019). Estimating soil nitrate leaching of nitrogen fertilizer from global meta-analysis. Science of the Total Environment, 657. https://doi.org/10.1016/j.scitotenv.2018.12.029

[8] Libutti, A., & Monteleone, M. (2017). Soil vs. groundwater: The quality dilemma. Managing nitrogen leaching and salinity control under irrigated agriculture in Mediterranean conditions. Agricultural Water Management, 186. https://doi.org/10.1016/j.agwat.2017.02.019

[9] Nila Rekha, P., Kanwar, R. S., Nayak, A. K., Hoang, C. K., & Pederson, C. H. (2011). Nitrate leaching to shallow groundwater systems from agricultural fields with different management practices. Journal of Environmental Monitoring, 13(9). https://doi.org/10.1039/c1em10120j

[10] Jabloun, M., Schelde, K., Tao, F., & Olesen, J. E. (2015). Effect of temperature and precipitation on nitrate leaching from organic cereal cropping systems in Denmark. European Journal of Agronomy, 62. https://doi.org/10.1016/j.eja.2014.09.007

[11] Yadav, S. N. (1997). Formulation and Estimation of Nitrate-Nitrogen Leaching from Corn Cultivation. Journal of Environmental Quality, 26(3). https://doi.org/10.2134/jeq1997.00472425002600030031x

[12] Bartzas, G., Tinivella, F., Medini, L., Zaharaki, D., & Komnitsas, K. (2015). Assessment of groundwater contamination risk in an agricultural area in north Italy. Information Processing inAgriculture, 2(2),109–129. https://doi.org/10.1016/j.inpa.2015.06.004

[13] Wu, J., Bian, J., Wan, H., Ma, Y., & Sun, X. (2021). Health risk assessment of groundwater nitrogen pollution in Songnen Plain. Ecotoxicology and Environmental Safety, 207, 111245.https://doi.org/10.1016/j.ecoenv.2020.11124

[14] Gao, Y., Yu, G., Luo, C., & Zhou, P. (2012). Groundwater Nitrogen Pollution and Assessment of Its Health Risks: A Case Study of a Typical Village in Rural-Urban Continuum, China. PLoS ON7(4), e33982. https://doi.org/10.1371/journal.pone.0033982

[15] Isles - Gan. (2022). https://isles.gov.mv/Island/DetailsEn/814

[16] Lai, Y., & Dzombak, D. A. (2021). Assessing the effect of changing ambient air temperature on water temperature and quality in drinking water distribution systems. Water (Switzerland), 13(14). https://doi.org/10.3390/w13141916

[17] Rajwa-Kuligiewicz, A., Bialik, R. J., & Rowiński, P. M. (2015). Dissolved oxygen and water temperature dynamics in lowland rivers over various timescales. Journal of Hydrology and Hydromechanics, 63(4). https://doi.org/10.1515/johh-2015-0041

[18] Rajanayaka, C., Weir, J., Barkle, G., Griffiths, G., & Hadfield, J. (2020). Assessing changes in nitrogen contamination in groundwater using water aging: Waikato River, New Zealand. Journal of Contaminant Hydrology, 234. https://doi.org/10.1016/j.jconhyd.2020.103686

[19]

[20] Uddin, M. G., Nash, S., & Olbert, A. I. (2021). A review of water quality index models and their use for assessing surface water quality. In Ecological Indicators (Vol. 122). https://doi.org/10.1016/j.ecolind.2020.107218

[21]

[22] Krzywinski, M., Altman, N. Significance, P values and t-tests. Nat Methods 10, 1041–1042 (2013). https://doi.org/10.1038/nmeth.2698

[23]

[24] Stevens, G. M. W., & Froman, N. (2019). Chapter 10 - The Maldives Archipelago. In World Seas: an Environmental Evaluation (Second Edition).

Appendix

1. Calculation of water quality index using Microsoft excel sheet

Parameters	WHO Standard	1/Sn	Σ 1/Sn	K= 1/(Σ 1/Sn)	Wi = K/Sn	Ideal Value(Vo)	Mean Value (Vn)	Vn/Sn	Vn/Sn *100 = Qn	WnQn
PH	8.5	0.1176	5.4801	0.1825	0.0215	7.0000	7.56	0.3733	37.333	0.8015
Alkalinity mg/L CaC03	200	0.0050	5.4801	0.1825	0.0009	0.0000	316.8	1.5840	158.400	0.1445
Conductivity (uS/cm)	400	0.0025	5.4801	0.1825	0.0005	0.0000	692	1.7300	173.000	0.0789
TDS (mg/L)	600	0.0017	5.4801	0.1825	0.0003	0.0000	366.7	0.6112	61.117	0.0186
Nitrite (mg/L)	3	0.3333	5.4801	0.1825	0.0608	0.0000	1.18	0.3933	39.333	2.3925
Nitrate(mg/L)	50	0.0200	5.4801	0.1825	0.0036	0.0000	0.056	0.0011	0.112	0.0004
Nitrogen Ammonia (mg/L)	0.2	5.0000	5.4801	0.1825	0.9124	0.0000	0.526	2.6300	263.000	239.9571
		5.4801			1.0000					243.393

Parameters	WHO Standard	1/Sn	Σ 1/Sn	K= 1/(Σ 1/Sn)	Wi = K/Sn	Ideal Value(Vo)	Mean Value (Vn)	Vn/Sn	Vn/Sn *100 = Qn	WnQn
PH	8.5	0.1176	5.4801	0.1825	0.0215	7.0000	7.51	0.3400	34.000	0.7299
Alkalinity mg/L CaC03	200	0.0050	5.4801	0.1825	0.0009	0.0000	392	1.9600	196.000	0.1788
Conductivity (uS/cm)	400	0.0025	5.4801	0.1825	0.0005	0.0000	726	1.8150	181.500	0.0828
TDS (mg/L)	600	0.0017	5.4801	0.1825	0.0003	0.0000	750	1.2500	125.000	0.0380
Nitrite (mg/L)	3	0.3333	5.4801	0.1825	0.0608	0.0000	2.04	0.6800	68.000	4.1361
Nitrate(mg/L)	50	0.0200	5.4801	0.1825	0.0036	0.0000	0.0094	0.0002	0.019	0.0001
Nitrogen Ammonia (mg/L)	0.2	5.0000	5.4801	0.1825	0.9124	0.0000	0.28	1.4000	140.000	127.7338
		5.4801			1.0000					132.900

Parameters	WHO Standard	1/Sn	Σ 1/Sn	K= 1/(Σ 1/Sn)	Wi = K/Sn	Ideal Value(Vo)	Mean Value (Vn)	Vn/Sn	Vn/Sn *100 = Qn	WnQn
PH	8.5	0.1176	5.4801	0.1825	0.0215	7.0000	7.61	0.4067	40.667	0.8730
Alkalinity mg/L CaC03	200	0.0050	5.4801	0.1825	0.0009	0.0000	443	2.2150	221.500	0.2021
Conductivity (uS/cm)	400	0.0025	5.4801	0.1825	0.0005	0.0000	12570	31.4250	3142.500	1.4336
TDS (mg/L)	600	0.0017	5.4801	0.1825	0.0003	0.0000	12570	20.9500	2095.000	0.6371
Nitrite (mg/L)	3	0.3333	5.4801	0.1825	0.0608	0.0000	4.6	1.5333	153.333	9.3266
Nitrate(mg/L)	50	0.0200	5.4801	0.1825	0.0036	0.0000	0.33	0.0066	0.660	0.0024
Nitrogen Ammonia (mg/L)	0.2	5.0000	5.4801	0.1825	0.9124	0.0000	0.4	2.0000	200.000	182.4769
		5.4801			1.0000					194.952

WQI Developed by Brown	
Water Quality	Quality Status
0-25	Excellet
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unfit for consumption

2. illustration of method to quantify amount of nitrate, nitrite and nitrogen ammonia