Physicochemical Profiling of Soil and Water from the Industrial Area of Selaqui in Uttarakhand and the Effect of Effluent on Fertility Parameters of Soil

Om Dubey[1]*, Manendra S Chauhan[2], Neha Bhatt[3], Venkatanarayana Pappula[4], Ankita Ravani[5]

[1,2,3]School of Allied Science, Dev Bhoomi Uttarakhand University, Dehradun, India

[4]School of Technology, Woxen University, Hyderabad, Telangana, India

[5]Dharmsinh Desai University, Nadiad, India

***Email:** omforensic@gmail.com

Abstract

Since the existence of Uttarakhand as a new state, it has given many business opportunities to industrialists to invest in the state's economic growth. The pharmaceutical industry is one such sector that has grown exponentially in the spatial region of Uttarakhand, along with many other industries located in the Selaqui industrial area. The industries housed in the industrial region of Dehradun provide medicine, machinery, tools, and other types of equipment to society. The manufacturing and packaging process generates wastewater that has to be treated before being released from the industrial premise and into the nearby stream. If regular monitoring is not done, the industry's effluents may threaten human health and the environment. The present study was a holistic approach to analyzing the effluents released from the industry region, their possible hazard and threats to the soil, and the physicochemical profile of the soil. At the end of the study, the authors have concluded that the physical and chemical properties of water are found to be within the permissible limit as given by different monitoring agencies. There is no heavy metal contamination, and the Nitrogen, Phosphorus and Potassium (NPK) value for the fertile soil has been retained within the limit of the Bureau of Indian Standards (BIS) and falls within the limits of the World Health Organization (WHO).

KeywordsEffluent; physicochemical profiling; industrial waste; soil toxicity;waste water

Introduction

Uttarakhand is a young state carved out from Uttar Pradesh, located in the northern part of the Indian subcontinent. The new state has its own charm and calamity. Although there are many benefits to be enjoyed by the state in political terms, the state had invited discomfort when the industrial opportunities were spread out in many regions of Uttarakhand where small to big industries made their presence. Along with them, they brought a few dynamic things like an increase in population and pollution, which at times becomes stressful for the original inhabitants of the state as well as the environmental inhibition also starts struggling. This study is conducted to identify the physicochemical and biological stress in the effluent from industries located in the Selaqui region of Uttarakhand state, as well as the chemical and physical properties of soil for agricultural use. The study results will be evaluated along with the standards from the Bureau of Indian Standard, Central Pollution Control Board India (CPCB), and the WHO. The area chosen for our study is Pharma City II because many of the manufacturing and packaging industries are housed in this area, encompassing 60.46 Acres of land. State Infrastructure & Industrial Development Corporation Uttarakhand (SIIDCUL) is a government regulatory body for industries in Uttarakhand that gives land to industries on a lease basis or sells it; industries that are housed in the region of our study include some of the prominent pharmaceutical products manufacturing units which are listed below in the Table 1[1].

Table 1: Pharmaceutical industries existing in Selaqui industrial region

Sl. No.	Industry Type	Sl. No.	Industry Type
1	Generic Drugs	7	Cardiovascular Drugs
2	Biopharmaceuticals	8	Drug Intermediaries
3	Patented Drugs	9	Cardiovascular Equipments
4	Complex Generic Drugs	10	Capsules
5	Special Empty Capsules	11	Medical Devices
6	Auto-Immune Drugs	12	Other Consumer Plastic Products

Apart from the industries listed above there are various other industries which are contributing to pollution in the region of our study and are listed in table 2 [2]:

Table 2: Industries other than pharmaceutical present inSelaqui

Sl. No.	Industry	Sl. No.	Industry
1	Chemical Industry	6	Textile
2	Paint & Varnish	7	Automobile
3	Synthetic Resin	8	Liquefaction Process
4	Dye Synthesis	9	Plastic
5	Metal Plating	10	Fibre Glass

Industries generate employment for many[3], provide medicine to sufferers, and cure the needy[4]. Still, there are grey areas that are sometimes neglected by the bureaucrats and the big money-making giants. These grey areas include overexploitation of natural resources like water, forest, and agricultural land [5]. There is also increased pollution in the form of water, air, or soil which keeps on growing daily, and when the threshold limit breaks, there is an increased number of diseases and menaces which are sometimes incurable[6]. Water and soil are the primary living sources because we depend on water for daily activities like bathing, washing, drinking, and irrigation, while healthy soil is key to rich crop cultivation[7]. Therefore, both the water and soil need to be healthy and free from impurities for healthy living. Still, instances like industrialization have led to a makeshift in the lifestyle and health of living beings because of obvious reasons like the change in the quality of potable water and contamination of soil[8]. Using wastewater as effluents from the pharmaceutical industry is diverted to a nearby canal. It is often used for irrigating crops and vegetables[9], which may change the soil's physicochemical properties and microbiome, resulting in the soil's loss of productivity and increased human health risk [10]. Wastewater is used for irrigation when the water demand exceeds the actual supply[11]. The raised toxic elements in water and soil cause chronic diseases and are also subject to toxicological identification and analysis[12]. One good reason for carrying out the present study is that there is widespread agricultural land near the industrial area where people directly grow the crops and vegetables for their consumption and use water from the nearby stream to irrigate the same. Another reason for conducting the present study is to check the quality of water released from the industrial region. Apart from the two reasons stated, the other advantage of physicochemical profiling of the soil and water is that the soil can show the domination of certain elements which can prove to be the signature of that particular area which can be of great help to the investigating agencies where if unidentified dead bodies are found then based on dominant trace element present in the soil the agency can locate the exact area of offence if there has been the transfer of soil from one place to another [13], this is what we also call the identity of the place [14]. In addition to the reasons stated in the present study, the imbalance in the physicochemical properties of the soil will also lead to poor crop yield. The effluents released may seep down the ground and meet the water table, affecting drinking water quality in places where people practice drinking water directly pumped from the ground. The previous studies which have been conducted are found to show limited parameters for the examination of water, but the present study has included both the water and soil physicochemical profiling and their influence on the fertility of the crop grown in nearby places.

Industrialization and Urbanization generate revenue for a particular state. However, it also negatively impacts the environment, sometimes proving to threaten soil and water. In the previous study conducted[15], authors have shown how heavy metals affect the soil quality in terms of crop cultivation and negative health impact on human beings. When we talk about the economy of the country, in that case, industries are thought to be the backbone of any nation. In parallel to the above context industries have also proved to be unsafe for the environment, and human beings be it in terms of mechanical accidents or mass disasters in terms of chronic effects that are developed as a result of waste that is being released without proper treatment and lack of safe disposal; as a result, many trace elements which prove to be harmful are recorded in the water and soil in and around the industry and the same has been shown by another author[16] in their study. Although some metals are essential for the growth of plants and animals, if present in increased quantities, they can also cause toxicity to plants and humans[17]. The effluents containing heavy metals not suitable for our health can pass to the food table through the cultivated crops in such areas. The statement has been proved to be true in the study conducted by authors[18], who found Cadmium in the wheat crop cultivated by the wastewater. Harmful elements can pass through the food chain and directly through the subcutaneous layer or be inhaled even in the vapour form. One study was conducted where Thallium was detected in the hair[19]. In the study performed by another author [20] they tabulated a six-step method to be adopted for the waste management of hazardous pharmaceutical products.

Pollution Reduction

One study showed how waste in water and soil could be reduced by adopting six effective methods like Reduction in waste, Recycling, Incineration, Composting, Sanitary Landfill, and Disposal in Ocean and Sea[21]. Photocatalysis is another contemporary method used to eradicate pharmaceutical drugs from the wastewater being released from the industries [22]. There has been a study even for the groundwater of industrial areas, which shows that treated wastewater is less potent than the groundwater contaminated by industrial waste[23]. All the above contaminants released from Pharmaceutical manufacturing companies as effluents are in addition to the waste that the healthcare sectors have to discard and dispose of and are calculated to be around 4057 tonnes per day [24].

Material and methods

The industrial region of Selaqui in Dehradun has been chosen for the present study. The sample collection is straight from the industrial hub of manufacturing units for tools, heavy machinery, pharmaceuticals, packaging, and small processing units. For the collection of water and soil samples, sterilised plastic containers have been used with air-tight seals[25][26]. Composite and continuous sampling techniques for water and soil are adopted for the sample collection in real-time [27]. Soil sample collection is done using a trowel to dig out the vertical 10 cm depth below the surface level[28]. The geographical coordinates for the collected effluent sample are 30.3705620 North and 77.8545630 East, with an altitude of 528meters above sea level. The agricultural soil is collected from the nearby field, which is irrigated by the water released from the industrial area whose geographical coordinates is noted as 30.3654160 North and 77.843080 East with an altitude of 513 metres above sea level. The control soil sample is collected from a distant region where there is no scope for industry pollutants being released. The sample soil and control soil is collected in a sterilized polybag, and the coordinates are 30.3842270 North and 78.0209980 East, with an altitude of 674 metres above sea level.The figure 1 below shows the locations where the test sample and control samples were collected forour study, the imageis only for representational purpose, and the map need not be scaled.

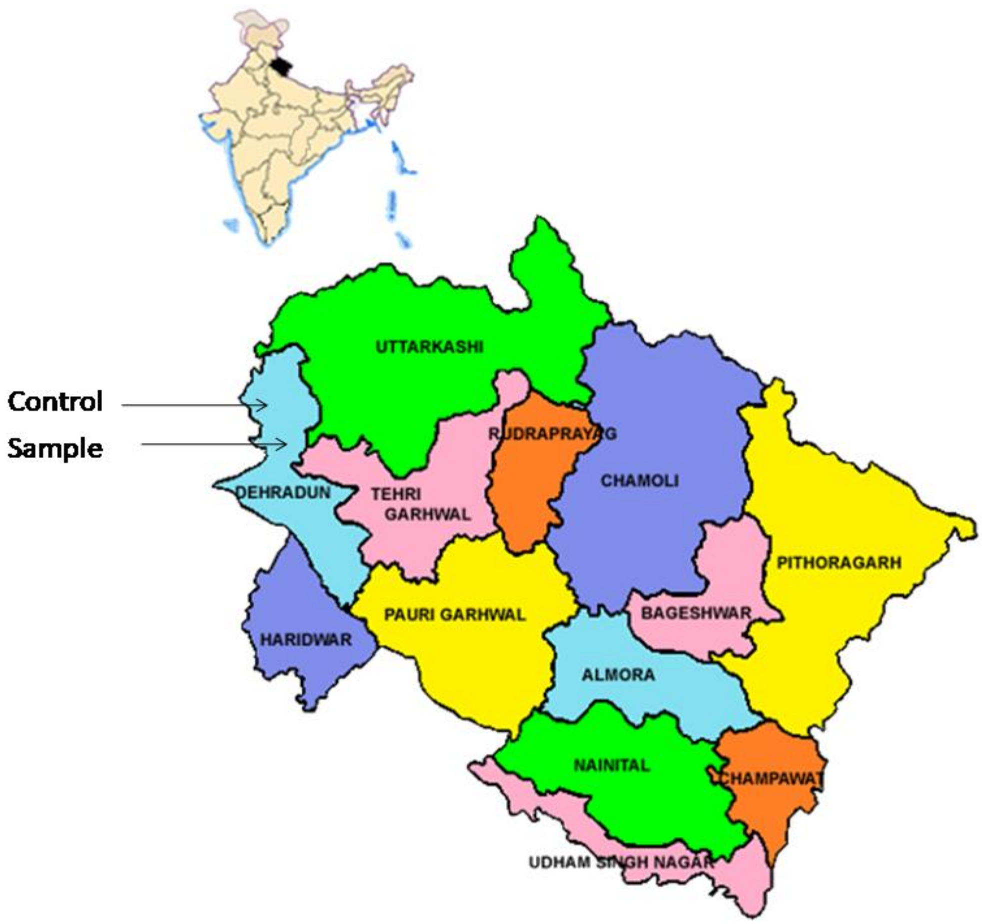

Figure 1: Area of our study where the water and soil samples have been collected

The table 3 below shows the parameters that have been considered for analyzing water and soil samples collected from Selaqui, Dehradun region located in the Uttarakhand state of India. The parameters adopted for testing the specimen are the same as those adopted by the CPCB of India and are synoptical to the WHO.

Table 3: Parameters chosen for the study of soil and water

Sl. No.	Parameter for Soil Test	Parameter for Water Test
1	PH	Copper
2	Moisture	Cadmium
3	Porosity	Manganese
4	Water Holding Capacity	Nickel
5	Conductivity	Lead
6	Carbon	Chromium Hexavalent
7	Nitrogen	Iron
8	Ammonia	TDS (Total Dissolved Solids)
9	Phosphorous	TSS (Total Suspended Solids)
10	Potassium	BOD (Biological Oxygen Demand)
11	Magnesium	COD (Chemical Oxygen Demand)
12	Calcium	
13	Sulphur	
14	Chloride	

Methodology

For the analysis of soil samples, different methodologies that can be adopted are classified broadly under three categories: physical, chemical, and mineralogical[29]. The table 4 below shows the methods we adopted to test the effluent released from the industrial site and table 5 shows the methodology adopted for analysis of soil samples collected from the nearby agricultural fieldof Selaquiand control soil sample.

Table 4: Methods adopted for the analysis of water collected from industrial area

Sl. No.	Parameter	Methodology
1.	Copper	Atomic Absorption Spectroscopy (AAS)
2.	Cadmium	AAS
3.	Manganese	AAS
4.	Nickel	AAS
5.	Lead	AAS
6.	Chromium Hexavalent	Diphenylcarbazide Method
7.	Iron	Phenanthroline Method
8.	TDS (Total Dissolved Solids)	Gravimetric Method
9.	TSS (Total Suspended Solids)	Gravimetric Method
10.	BOD (Biological Oxygen Demand)	Wrinkler Method
11.	COD (Chemical Oxygen Demand)	Open Reflux Method

Table 5: Methods adopted for the analysis of soil collected from industrial area and control soil sample

Sl. No.	Parameter	Methodology
1.	PH	Electrometric Method
2.	Moisture	Gravimetric Method
3.	Porosity	Saturation Method
4.	Water Holding Capacity	Water Retention Method
5.	Conductivity	Conductivity Meter
6.	Carbon	Walkley and Black Method
7.	Nitrogen	Kjeldhal Method
8.	Ammonia	Nesslerisation Method
9.	Phosphorous	Oslen Method
10.	Potassium	Flame Photometer
11.	Magnesium	Versanate Method
12.	Calcium	Versanate Method
13.	Sulphur	Turbidity Method
14.	Chloride	Argentometric Method

Food and Agriculture Organisations (FAO) of the United Nations (UN) have set limitations and marked standards for the water to be utilised for Irrigation, and the same is displayed in the supporting information (SI) Table SI1. These limitations have been taken as standards for comparison with the results that will be available for the soil samples to be tested.

The permissible limit for the effluents released from the industry by Bureau of Indian Standard (BIS)[30] is shown in the table 7 below.

Table 7: Limitation set by BIS for effluents released from industrial region

Sl. No.	Parameter	Limit
1	Copper	5.00
2	Cadmium	0.50
3	Manganese	-
4	Nickel	2.00
5	Lead	10.00
6	Chromium Hexavalent	1.00
7	Iron	20.00
8	TDS (Total Dissolved Solids)	-
9	TSS (Total Suspended Solids)	200
10	BOD (Biological Oxygen Demand)	100
11	COD (Chemical Oxygen Demand)	-

According to the laboratory manual released for soil testing by the Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India (GoI) there has been a soil fertility index as can be seen in the SI Table SI2.The Water holding capacity varies with the texture of the soil and is not uniform throughout. The soil texture varies between very coarse sands to clays, and the water holding capacity in the unit of inches of water per foot of soil will vary between 0.4 to 2.50; therefore, no standard parameter is given. Depending on the selection of our sample, the range is expected to be between 0.4 - 2.30

Results and discussion

A rigorous examination of effluent collected from the industrial site and soil samples collected from the agricultural site near Selaqui has been performed. For the Water analysis result that has been obtained isshown in table 8 below.

Table 8: Result of Selaqui effluent analysis

Sl. No.	Parameter	Selaqui Effluent (mg/L)
1	Copper	BDL
2	Cadmium	BDL
3	Manganese	BDL
4	Nickel	BDL
5	Lead	BDL
6	Chromium Hexavalent	BDL
7	Iron	0.08
8	TDS (Total Dissolved Solids)	324
9	TSS (Total Suspended Solids)	12.0
10	BOD (Biological Oxygen Demand)	8.12
11	COD (Chemical Oxygen Demand)	38.0

After the complete analysis of agricultural site soil sample and the control site sample,results have been obtained and the same is reflected in SI table SI3.

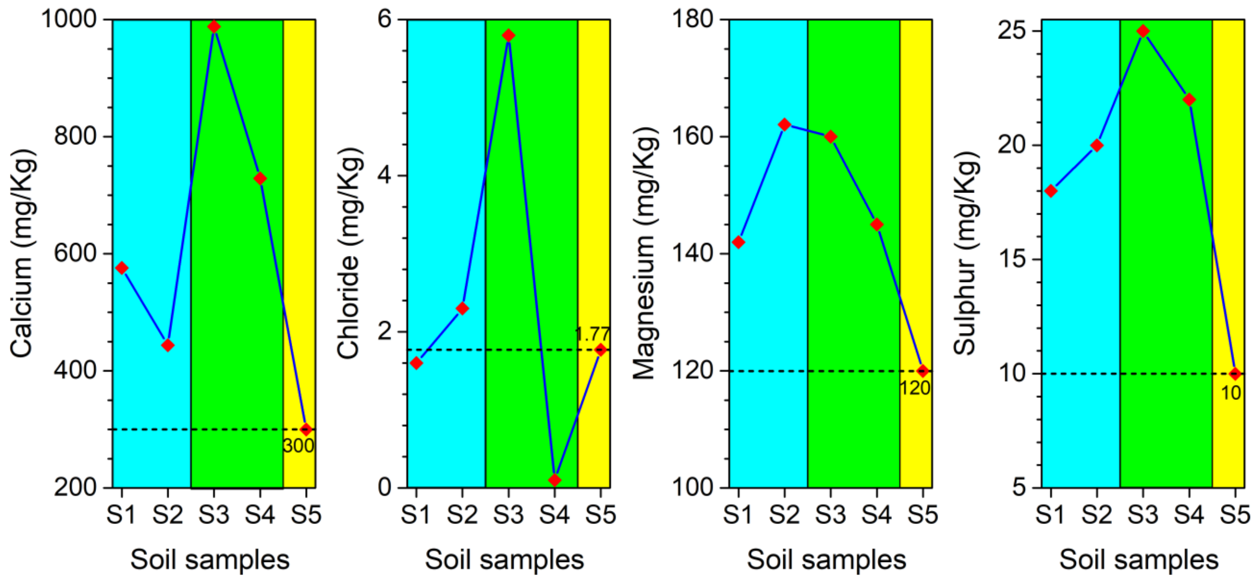

Figure 2: Comparative graph between different parameters and the soil samples.

In figure number 2, figure number 3, figure number 4, figure number 5, and figure 6, S1 indicates the outcome of the soil sample tested from Selaqui region S2 indicates the reading of the control soil sample S3 indicates the results obtained from Panipat region S4 represents the reading of Jalpaiguri. In the end, S5 reflects the limitations marked by GoI.

As we can observe from figure 2 the standard level of calcium in soil is 300mg/kg and in all the soil samples tested, the quantity is found to be exceeded. Calcium helps build the clay mass, which is suitable for aeration and helps increase soil fertility. Chloride concentration, essential for osmoregulation in plants, is less in the S1 and S4 samples, whereas in S2 and S3 the chloride concentration is found to be above the reference level. While the reference value for magnesium is 120mg/kg, and all four soil samples are found to have a concentration above the reference value. The shortage of magnesium may cause poor plant growth because magnesium is the key to chlorophyll. Sulphur held in soil is 10mg/kg for the fertile soil as it helps the plant make amino acids converted to protein. In all four samples, the value is found to be above the reference level.

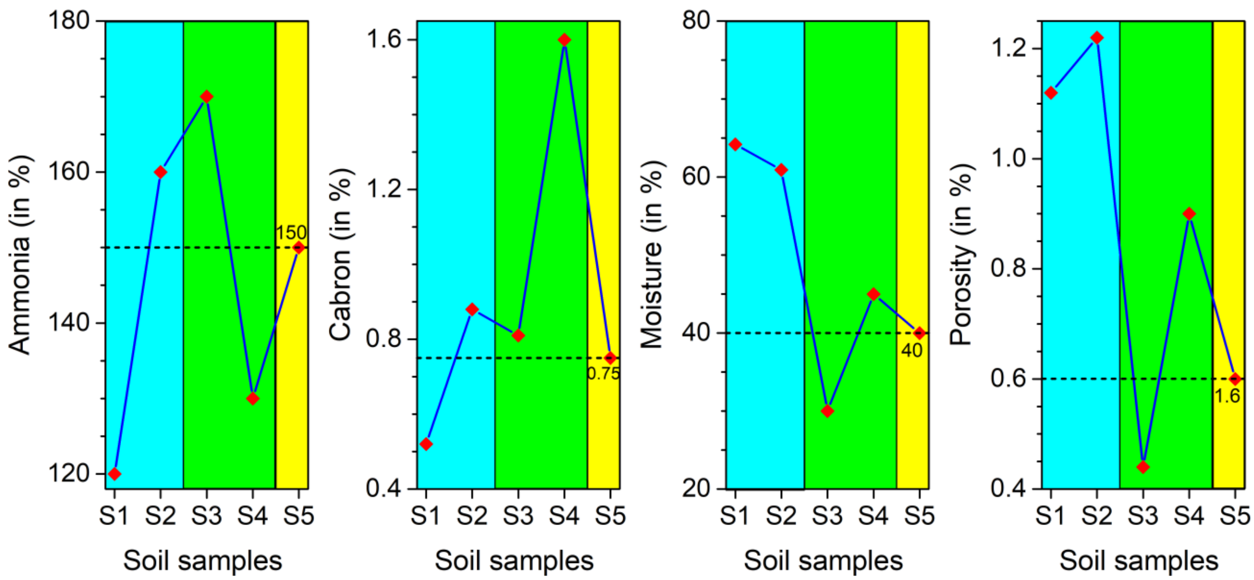

Figure 3: Comparative graph between different parameters and the soil samples.

In figure 3 reference value for ammonia is 150%, which is plants' primary source of nitrogen. S1 is found to be significantly less while S2, S3 are found to be in sufficient concentration, whereas S4 is below the required concentration. Carbon is the main component of soil, and the concentration value assigned is 0.75% which is found to be significantly less in selaqui region and high in Jalpaiguri region. In contrast, the carbon percentage is close to the reference value in S2 and S3. Moisture percentage found to be idle for the development of a plant is 40%, which is good in test and control samples. The porosity of the test and control soil is found to be above the reference value.

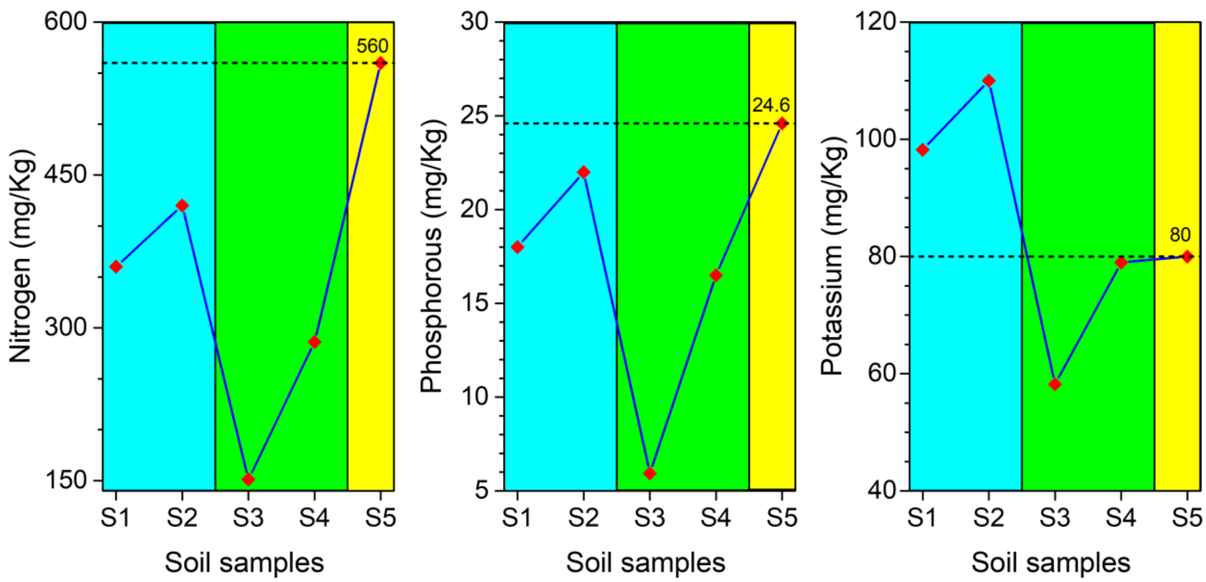

Figure 4: Comparative graph between different parameters and the soil samples.

In figure 4, the essential elements for the growth of plants are displayed, which is also frequently referred to as NPK value which stands for Nitrogen, Phosphorous, and Potassium. Nitrogen and Phosphorous amounts are below the reference value in all the soil samples. Potassium is above the reference value in test and control samples, whereas S3 and S4 are detected below the required value.

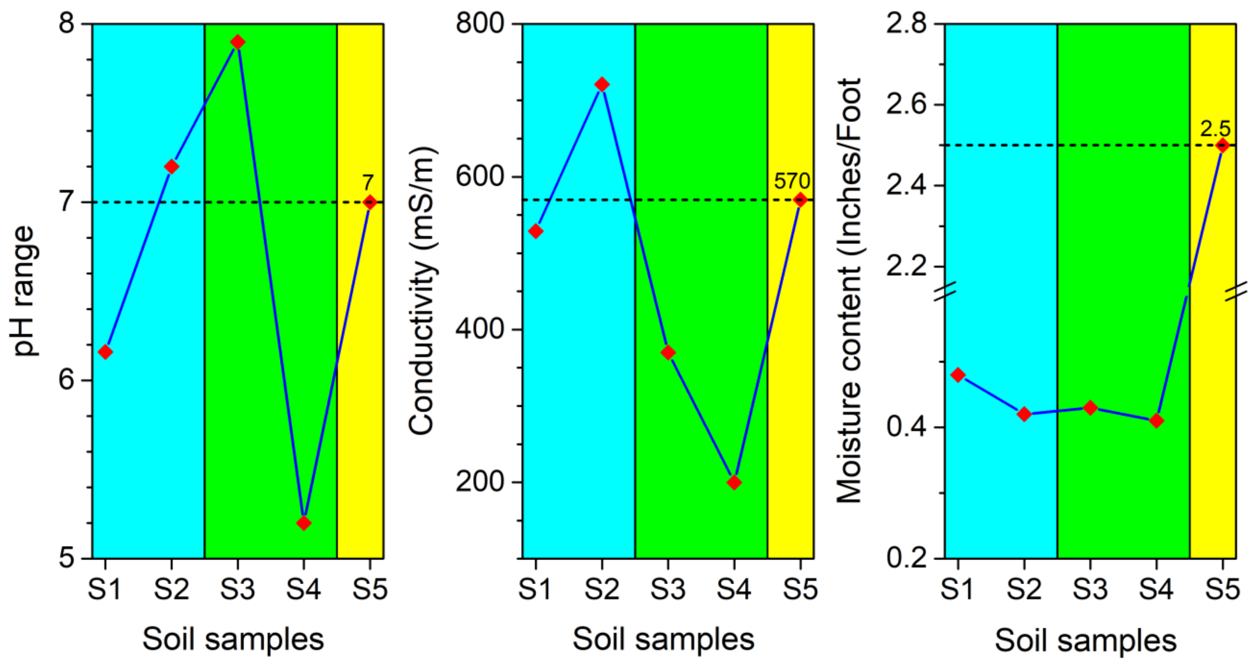

Figure 5: Comparative graph between different parameters and the soil samples.

Soil pH affects the nutrients that are soluble in water because it is found that few nutrients required are available in acidic conditions. At the same time, some nutrients are soluble under alkaline conditions [31]. As seen in figure number 5, S1 and S2 pH is close to the reference value, whereas in S4, it is found to be acidic, and S3 of basic pH. The soil's conductivity shows the nutrients and water availability in the soil [32]. The conductivity of S4 is significantly less compared to the S2 sample, whereas S1 and S3 are close to the reference value of conductivity. Plant growth relies on the fact that soil is hydrated in arid and semi-arid regions. Lack of soil moisture will lead to a lack of nutrition and water for the plant and eventually can dry [33]. Water holding capacity reflects the amount of water required for the plants to grow in a specific area, eventually helping the nutrition get transported to different regions within the plant [34].

Table SI4 shows the comparison between the limitations marked by WHO and BIS and the result obtained from the examination of waste water discharge from the Selaqui industrial area.

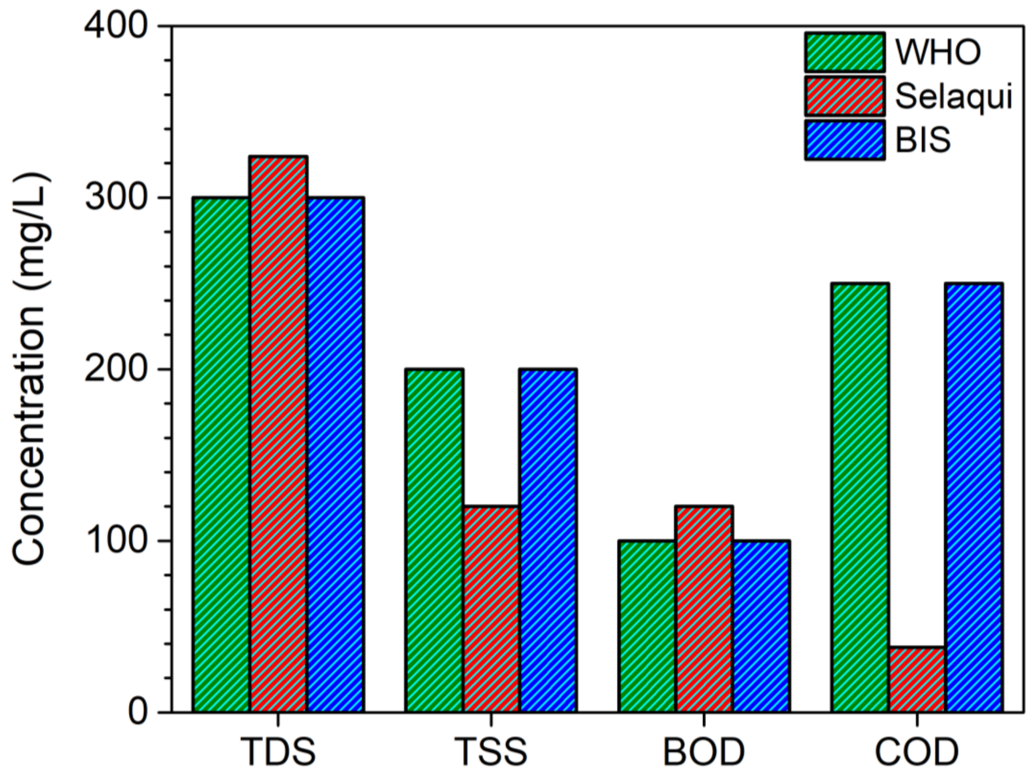

Figure 6: Comparative graph between different standards and the effluent sample.

It is observed from the above figure 6 that the detected value of the effluent collected from the industrial area of Selaqui is within the permissible limit set by the Bureau of Indian Standard and World Health Organization, whether it is about the heavy metals or other parameters. Total Suspended Solids (TSS) is the amount of solid matter suspended in the water that can be held back during filtration. TSS is supposed to contain degraded organic and inorganic substances, silt, sewage, and industrial discharge. Total Dissolved Solids (TDS) are the number of solid substances dissolved in water and can pass through the filter easily. Few metals and organic ions are required for the essential development of living organisms; therefore, they are already present in water.

The above figure shows that the pH of the soil sample collected from the Selaqui industrial area is very close to the control soil sample and the limit set by the GoI. The conductivity of the soil from the industrial region is increased compared to the limitation set by GoI. Moisture is increased when compared to the threshold of the GoI. When the NPK level was detected and compared to the limitation given by GoI, it was found that nitrogen and phosphorus were below the permissible limit, and potassium was elevated from the reference value of GoI. The physicochemistry of water released from the industrial area of Selaqui is found to be within the permissible limit of the Bureau of Indian Standard and the World Health Organisation.

Conclusions

The soil study conducted above, in conjunction with wastewater released from the Selaqui industrial area in the Uttarakhand region of India, has revealed encouraging and positive results. It is concluded from the above observations and results that the wastewater discharge from the industrial region contains no harmful traces of heavy metals or similar harmful elements that can cause fluctuation in soil fertility. The authors were satisfied and pleased to conclude from their study that the physiochemical property of the soil is not affected when compared to the limitations laid down by the Government of India. The physiochemical parameters of control soil samples are also found to be close to the BIS and GoI guidelines. The previous study conducted [35] over the wastewater discharge of Selaqui, when read in par with the present study, has shown that the physiochemical properties, which had a large margin in the previous study, have now been recovered and have a significantly less gap.

Abbreviation

BDL – Below Detection Limit

BIS- Bureau of Indian Standard

CPCB- Central Pollution Control Board India

FAO- Food and Agricultural Organization

GoI- Government of India

Mg/Kg – Milligram per Kilogram

Mg/L – Milligram per Liter

mS/m – Millisiemens per meter

Sl.No. – Serial Number

SI- Supplementary Information

WHO- World Health Organization

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Conflict of Interest

Authors declare that there is no conflict of interest among them.

Ethical Declaration

No human or animal subjects were used in the present study therefore it is not applicable.

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Physicochemical profiling of soil and water from the industrial area of Selaqui in Uttarakhand and the effect of effluent on fertility parameters of soil

Om Dubey[1]*, Manendra S Chauhan[2], Neha Bhatt[3], Venkatanarayana Pappula[4], Ankita Ravani[5]
[1,2,3]School of Allied Science, Dev Bhoomi Uttarakhand University, Dehradun, India
[4]School of Technology, Woxen University, Hyderabad, Telangana, India
[5]Dharmsinh Desai University, Nadiad, India

***Email:** omforensic@gmail.com

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Table SI1: Permissible **c**oncentration of elements in water as stated by WHO for irrigation[1].

Sl. No.	Element	Concentration (mg/L)
1	Al	5.0
2	As	0.10
3	Be	0.10
4	Cd	0.10
5	Co	0.05
6	Cr	0.10
7	Cu	0.20
8	F	1.0
9	Fe	5.0
10	Li	2.5
11	Mn	0.20
12	Mo	0.01
13	Ni	0.20
14	Pb	5.0
15	Se	0.02
16	Sn	-
17	Ti	-
18	W	-
19	V	0.10
20	Zn	2.0

Table SI2: Comparative test results of soil samples evaluated from different places within India

Parameter	Limitations (GoI) [2]	Selaqui	Control	Panipat[3]	Jalpaiguri[4]
pH	7	6.16	7.20	7.90	5.2
Conductivity *(mS/m)*	570	529	721	370	200
Chloride *(mg/Kg)*	1.77	1.6	2.3	5.8	0.10
Potassium *(mg/Kg)*	80	98.23	110.0	58.21	79
Carbon *(%)*	0.75	0.52	0.88	0.81	1.60
Nitrogen *(mg/kg)*	560	360	420	151.23	286
Moisture *(%)*	40	64.20	60.91	30	45
Ammonia *(%)*	150	120	160	170	130
Sulphur *(mg/Kg)*	10	18	20	25	22
Water Holding Capacity *(Inches/Foot))*	0.4-2.50	0.48	0.42	0.43	0.41
Porosity *(%)*	0.60	1.12	1.22	0.44	0.9
Phosphorous *(mg/kg)*	24.6	18.0	22.0	5.93	16.5
Magnesium *(mg/Kg)*	120	142.0	162.1	160	145
Calcium *(mg/Kg)*	300	576	444	98.83	0.729

Table SI3: Tested value of Soil Samples from industrial region and control soil sample.

Parameter	Selaqui	Control
pH	6.16	7.20
Conductivity *(mS/m)*	529	721
Chloride *(mg/Kg)*	1.6	2.3
Potassium *(mg/Kg)*	98.23	110.0
Carbon *(%)*	0.52	0.88
Nitrogen *(%)*	360	420
Moisture *(%)*	64.20	60.91
Ammonia mg/kg*()*	120	160
Sulphur *(mg/Kg)*	18	20
Water Holding Capacity *(Inches/Foot)*	0.48	0.42
Porosity *(%)*	1.12	1.22
Phosphorous *(%*	18.0	22.0
Magnesium *(mg/Kg)*	142.0	162.1
Calcium *(mg/Kg)*	576	444

Table SI4: Comparison among limitation set by WHO & BIS with effluent from Selaqui.

Sl. No.	Parameter	WHO Standard (mg/L)	Selaqui Sample (mg/L)	BIS Standard (mg/L)
1.	Copper	2.0	BDL	5.00
2.	Cadmium	0.003	BDL	0.50
3.	Manganese	0.4	BDL	-
4.	Nickel	0.07	BDL	2.00
5.	Lead	0.01	BDL	10.00
6.	Chromium Hexavalent	0.05	BDL	1.00
7.	Iron	0.3	0.08	0.3
8.	TDS (Total Dissolved Solids)	300	324	300
9.	TSS (Total Suspended Solids)	200	120	200
10.	BOD (Biological Oxygen Demand)	100	120	100
11.	COD (Chemical Oxygen Demand)	250	38.0	250

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