WATER & ENVIRONMENT

Center for Advanced Studies in Water
Mehran University of
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Preface

Water is the essence of life. As the most abundant molecule in human body cells, water accounts for 70% of the total cell mass. Body functions including food digestion, circulatory processes and lubrication of joints require water. It is also important for regulating body temperature. Without water there would be no vegetation on Earth and consequently no oxygen for breathing. In a nutshell, there won't be any life without water. Water significantly influences the ecological, biogeochemical and geomorphological processes and plays a critical role in the functioning of an ecosystem. Its critical role in photosynthesis and the circulation and movement of different elements in the ecosystem makes water invaluable.

Water is a key driver for economic and social development of any country. The fact that water is important for agriculture, energy, transport and all types of production industries proves that water plays a significant role in human societies. Agricultural economies like Pakistan, are heavily dependent on water. Considering the changes in global climate and their impacts on the water resources, it is necessary to focus on the study of our water resources and to give the required attention to sustainable development and proper management of water sector. The basic function of water in maintaining the integrity of the natural environment cannot be overlooked. Therefore, an integrated approach for managing water resources and addressing environmental issues is indispensable. Thus, knowing the importance of sustainable management of water and environmental issues in Pakistan, USPCAS-W, MUET, Jamshoro organized a Two-Day Young Researcher's National Conference on Water and Environment (NCWE-17).

The objective of this conference is to provide an ideal academic platform to young researchers and scholars from all over the country to present, share and exchange their latest findings about water and environment related issues. Papers on different themes were presented in parallel session to provide opportunities for delegates throughout the country to share their scholarly knowledge, skills and experience with focus on water, environment and communal challenges. The conference was focused on Sustainable Development Goals (SDGs) 1, 2, 6 and 13.

Editors
Dr. Rasool Bux Mahar
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ANALYSIS OF WATER QUALITY OF MUET WATER TREATMENT & DISTRIBUTION SYSTEM BY TAKING INTO ACCOUNT SEASONAL VARIATIONS

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Literature Review

This study was carried out to analyze the quality of water being supplied to MUET through its water Treatment and Distribution System (T&DS) by taking into account seasonal variations. This study also checked the performance of the MUET T&DS. The water for MUET T&DS is taken from K.B. Feeder canal which takes off from river Indus at Kotri barrage. The quality of the intake water was observed to be mainly dependent upon the quality of the water in the river Indus. Parameters including temperature, total dissolved solids (TDS), electrical conductivity, pH, DO and turbidity were measured on different sites of water treatment and distribution network on weekly basis from May 2016 to April 2017. Other than K.B. Feeder intake point, the sites in the water treatment plant include coagulation tank (in & out), slow sand filter and treated water storage tank in MUET treatment plant. On the other hand MUET storage tank of distribution system, Environmental Engineering (EE) department and Institute of Water Resources Engineering & Management (IWREM) were selected in water distribution network. However total Coliforms were analyzed in the department of EE, MUET, Jamshoro by collecting water samples from GM Syed Hostel, Latif Hostel, Post filter tank, Inlet Water Treatment Plant (WTP), Outlet WTP, IWREM, IEEM and Office of Research, Innovation and Commercializ
ation (ORIC) in the month of November and December 2016. The current water treatment system does not offer adequate disinfection as was indicated from positive results obtained after analyzing samples for Total coliform. The average values of temperature were exceeding WHO limit of 25ºC at all locations except slow sand filter and post filter storage tank. The average values of turbidity at all selected locations were exceeding limit set by WHO i.e. 5 NTU. Among all locations turbidity was maximum at intake (KB feeder). The mean of pH values at all locations is above 8 but still lies within standard limit i.e. 6.5-8.5. Total dissolved solids content at slow sand filter is exceeding WHO limit i.e. 500 mg/L. However it is below limit at all other locations. Dissolved oxygen in water is considered good when it is above 4 mg/L as set by WHO and at all selected locations DO is above 4 mg/L. Thus, the results show that there is need of comprehensive monitoring along with efforts to ensure compliance with standards set by WHO.

Keywords:

MUET, Water quality analysis, Water treatment and Distribution network.

Introduction

Mehran University of Engineering & Technology (MUET), Jamshoro, is striving for improving the quality of its drinking water. This is also required as per Sustainable Development Goals (SDGs). The university has set up a Water Treatment & Distribution System for treatment of water before supplying it to the campus. The treated water is being supplied to various departments, hostels and residences. MUET has eighteen (18) departments where more than seven thousand (7000) students are studying in various programs. The university has also twelve (12) hostels. Also, there are more than four hundred (400) faculty members and twelve hundred and fifty (1,250) supporting staff including officers. The water supplied to university is taken from KB Feeder which takes water from river Indus. The water is pumped from intake to the Water Treatment Plant (WTP) through a 12” diameter pipeline. The water treatment includes various processes i.e. coagulation, sedimentation, filtration and disinfection. The output of treated water is around 1 MGD. The water supplied is stored in storage tanks either underground or on top of the buildings. Most of the water demand is during working hours.

Literature Review

Water shortages are now becoming more and more prominent. The researchers are now focusing on intelligent water systems for utilization of available water. Mizuki et al. (2012) pointed out that water shortages due to rising population can be met by treatment of waste water and use of recycled water. The researchers stressed the need for efficient management of water circulation system and provision of water infrastructure systems. Other problems also emerge when adopting a complete approach for water treatment [1]. Mays (2000) identified different issues in water treatment such as mixing and aging in storage facilities, monitoring and sampling issues, modeling, design and operational issues and inspection & maintenance issues. These issues were highlighted in addition to water quality problems. Also, inefficient water supply system can also cause contamination in treated water. Ercumen et al. (2014) observed that water supply systems are prone to performance deficiencies which can again pollute the treated water thereby causing water borne diseases including gastrointestinal illnesses to water users. Therefore, effective water treatment strategy is very important for supply of potable water to consumers [2]. Dohare et al. (2014) researched that water quality depends on type of parameter present and pointed out that monitoring of water quality can be done by taking representative samples and assessing of pollutants at different locations by using suitable methods. The researcher observed that then statistical methods can be adopted to assess water quality for pre and post monsoon periods. Field methods for water quality examination have enhanced the way the water quality parameters are checked [3].Gibs et al. (2007) have listed out various field equipment’s for checking water quality parameters such as pH sensor, temperature sensor, DO polarographic sensor, turbidity sensor and ORP sensor [4].Khalid (2011) analyzed that chlorination can be adopted if contamination level is high along with efficient system of garbage removal, recycling and educating people for protection of healthy environment can help solve water shortage problem and reduce incidents of water borne illnesses. Thus, a gap exists in analyzing water quality in the MUET treatment and distribution system for adopting holistic approach as mentioned above and ensures unhindered safe supply of drinking water. The main aim of this study is to analyze the working of treatment plant and distribution system of MUET with focus on its efficiency and suggest modifications and redesigning if any. In addition to that this study is also carried out to analyze the samples of water collected from different locations of MUET water T&DS for temperature, turbidity, TDS, electrical conductivity, pH, DO and total coliforms.

Methodology

Site Selection:

For analyzing temperature, turbidity, total dissolved solids (TDS), electrical conductivity, pH and DO different sites of water treatment and distribution network were selected. The sites in water treatment network include K.B. Feeder intake point, coagulation tank (in & out), slow sand filter and treated water storage tank in MUET treatment plant. On the other hand MUET storage tank of distribution system, department of EE and IWREM sites were selected in water distribution network (see fig 3.1 below). However water samples for analyzing total coliforms were collected from GM Syed Hostel, Latif Hostel, Post filter tank, Inlet WTP, Outlet WTP, IWREM, EE and ORIC.

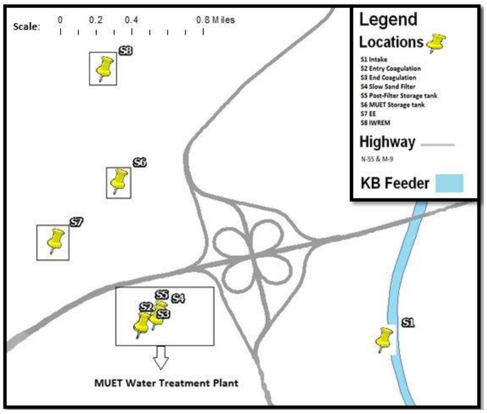


Fig 3.1. Sampling locations in MUET water T & DS

Sampling Procedure:

For analyzing temperature, turbidity, total dissolved solids (TDS), electrical conductivity, pH and DO, samples were analyzed on site for one year from May 2016 to April 2017on weekly basis in the morning hours i.e. between 10:00 a.m. to 02:00 p.m. However, for analyzing total coliforms different types of water samples (see Table 4.1.7) were collected once from selected locations in November and December 2016.

Methods and Instrument Used:

The portable water analyzing equipment i.e. YSI water logger was used for measuring temperature, TDS, electrical conductivity, pH and DO and for turbidity measurement HACH 2100Q Turbidimeter was used. All parameters were measured on the site. However Total coliforms (CFU/100 ml) were analyzed by Membrane Filtration Technique in the Laboratory of Environmental Engineering department, MUET, Jamshoro.

Results & Discussion

Statistical Analysis of Various Parameters at Selected Locations

Temperature

The values of temperature were exceeded at all locations except slow sand filter. But maximum temperature is obtained at IWREM i.e. 30.85 ℃. The higher temperature observed is due to taking readings in the latter part of the day i.e., after 12:00 pm.

Turbidity

The values of turbidity surpassed the limits fixed by WHO at all selected locations. The highest recorded values of turbidity are at intake, entry coagulation, and end coagulation. The highest turbidity at intake indicates KB feeder (source of water) as full of turbid material. In addition to that turbidity at coagulation (in and out) shows no Alum dosing is done to remove turbidity during coagulation. The higher values of turbidity are at Post-filter storage tank and MUET storage tank. However at slow sand filter and IWREM the value of turbidity is high, but is less than all other locations.

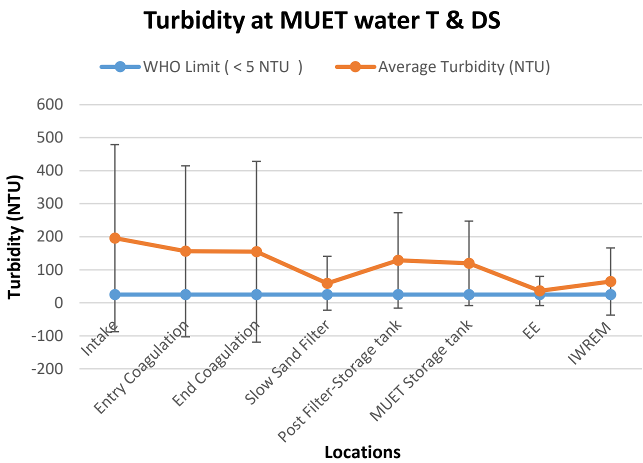


Fig 4.1.2 Average turbidity at different sites of MUET water T & DS

Total Dissolved Solids

Total dissolved solids represent organic and inorganic matter in the sample. A high concentration of dissolved solids upsurges the density of water which disturbs osmoregulation of fresh water organisms. In addition to that TDS, higher concentration lower down the solubility of gases and reduces the utility of water for drinking, irrigation and industrial purposes [5]. The Total Dissolved Solids (TDS) values at all the selected locations except at slow sand filter were lower than WHO standards.

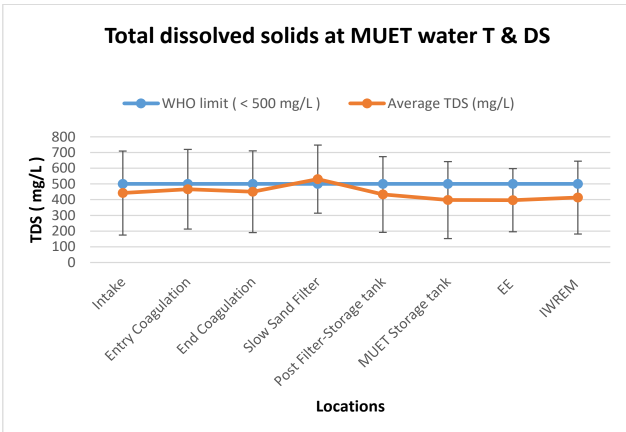


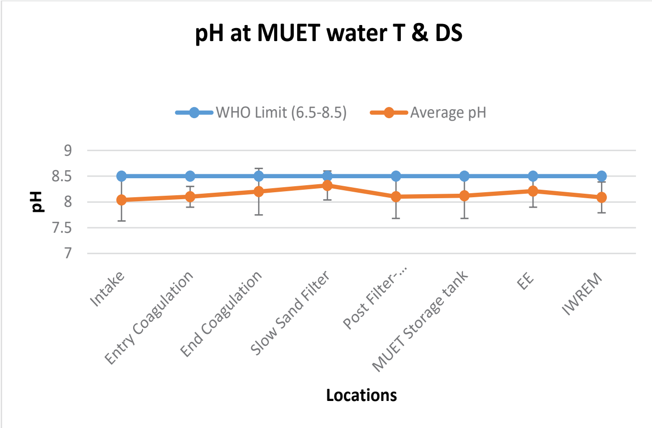
Fig 4.1.2 Average turbidity at different sites of MUET water T & DS

Electrical Conductivity

Electrical conductivity at all the selected locations is lower than the limits set by WHO. However, if we compare EC values between different sites, it is greater at slow sand filter as TDS value which indicates that EC and TDS are directly proportional to each other.

pH

The mean value of the pH at all selected locations is above 8. However, it still lies within permissible limits as set by WHO i.e. 6.5 to 8.5.



Dissolved Oxygen

Dissolved oxygen in water plays an important role and is considered as one of the factors which replicates physical and biological process taking place in a water body[5]. The DO at all selected sites is above 4 mg/L which indicates quality of water at all locations is suitable for drinking with respect to DO because higher value of dissolved oxygen can impart good visual taste to drinking water [6].

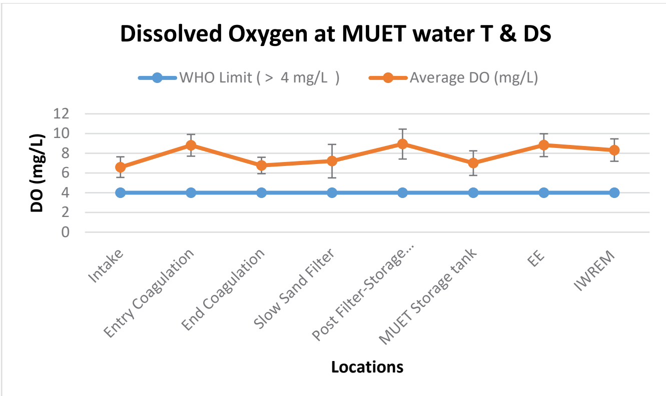


Figure 4.1.6 Average DO at different sites of MUET water T & DS

Total Coliforms

All samples of water at selected locations except GM Syed hostel (filtered water) are found contaminated with presence of total coliforms which are not suitable for drinking.

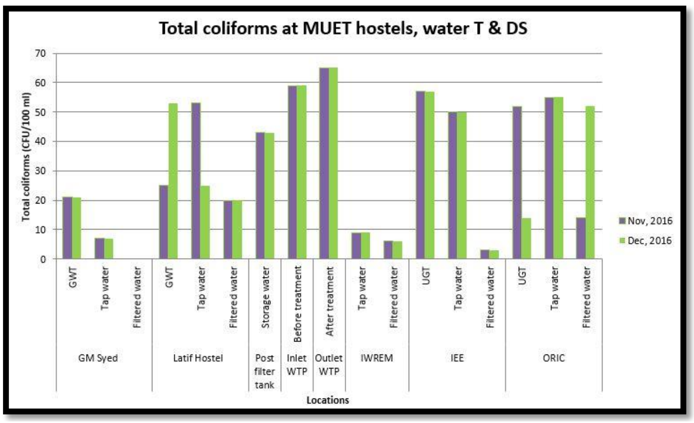


Figure 4.1.7 Total coliforms in different sources of water at different sites of MUET hostels, water T & DS

Table 4.1.7 Total coliforms in different sources of water at various locations

Sr. #	Sampling Location	Type of water	Total coliforms (CFU/100 ml)	
-	-	-	Nov, 2016	Dec, 2016
		GWT*	21	22
		Tap water	7	9
1	GM Syed Hostel	Filtered water	0	0
		GWT	25	50
		Tap water	53	23
2	Latif Hostel	Filtered water	20	23
3	Post filter tank	Storage water	43	45
4	Inlet WTP	Before treatment	59	54
5	Outlet WTP	After treatment	65	64
		Tap water	9	8
6	IWREM	Filtered water	6	3
		UGT**	57	55
		Tap water	50	40
7	IEE	Filtered water	3	5
		UGT	52	16
		Tap water	55	56
8	ORIC	Filtered water	14	54

GWT* = Groundwater

UGT* = Underground tank

Correlation between different parameters at selected locations

Intake

At intake, highly positive correlated values were found between TDS and EC (0.99) and highly negative correlated values were found between temperature and TDS (-0.87), temperature and EC (-0.84), turbidity and TDS (-0.81) and turbidity and EC (-0.81). Positive correlation was found between temperature and turbidity (0.78), TDS and pH (0.35), TDS and DO (0.26), EC and pH (0.36), EC and DO (0.25). However negative correlation was found between temperature and pH (-0.26), temperature and DO (-0.03), turbidity and pH (-0.29), turbidity and DO (-0.01), and pH and DO (-0.4).

Entry Coagulation

At Entry coagulation, highly positive correlation was found between TDS and EC (0.99) and highly negative correlation was found between turbidity and TDS (-0.81). Positive correlation exists between temperature and turbidity (0.79), turbidity and DO (0.43), TDS and pH (0.51), EC and pH (0.51). However negative correlation exists between TDS and DO, EC and DO, pH and DO, temperature with all parameters except turbidity, and turbidity with all parameters except DO.

End Coagulation

At End coagulation, highly positive correlation was found between TDS and EC (0.99). Positive correlation exist between temperature and turbidity (0.75), temperature and DO (0.11), turbidity and DO (0.63), TDS and pH (0.39), TDS and DO (0.23), EC and pH (0.51), and EC and DO (0.28). However negative correlation exists between pH and DO, temperature with all parameters except turbidity and DO, and turbidity with all parameters except DO.

Slow Sand Filter

At slow sand filter, highly positive correlation was found between TDS and EC (0.99). Positive correlation exists between temperature and turbidity (0.64), turbidity and DO (0.26), TDS and pH (0.35), TDS and DO (0.18), EC and pH (0.36), and EC and DO (0.13). However negative correlation exists between temperature with all parameters except turbidity, and turbidity with all parameters except DO.

Post Filter Storage Tank

At post filter storage tank, highly positive correlation was found between TDS and EC (0.99). Positive correlation exists between temperature and turbidity (0.73), TDS and pH (0.51), TDS and DO (0.05), EC and pH (0.51), and EC and DO (0.03). However negative correlation exists between temperature with all parameters except turbidity, and turbidity with all parameters.

Muet Storage Tank

At MUET storage tank, highly positive correlation was found between TDS and EC (0.99). Positive correlation exists between temperature and turbidity (0.70), turbidity and DO (0.02), TDS and pH (0.41), TDS and DO (0.15), EC and pH (0.41), and EC and DO (0.09). However negative correlation exist between pH and DO (-0.40), temperature with TDS, EC, pH, and DO with r value of -0.72, -0.68, -0.46 and -0.63 respectively and turbidity with all parameters except DO.

Ee Department

At EE department, highly positive correlation was found between TDS and EC (0.99). Positive correlation exists between temperature and turbidity (0.22), turbidity and DO (0.09), TDS and pH (0.18), EC and pH (0.18), and pH and DO (0.14). However negative correlation exist between TDS and DO (-0.34), EC and DO (-0.45), temperature with TDS, EC, pH, and DO with r value of -0.69, -0.63, -0.24 and -0.31 respectively and turbidity with TDS, EC and pH with r values of -0.25, -0.26 and -0.27 respectively.

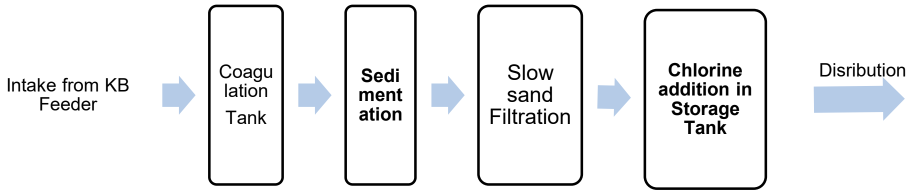
Iwrem

At IWREM, highly positive correlation was found between TDS and EC (0.99). Positive correlation exists between temperature and turbidity (0.31), turbidity and DO (0.21), TDS and pH (0.21), EC and pH (0.21). However negative correlation exist between TDS and DO (-0.39), EC and DO (-0.43), pH and DO (-0.14), temperature with TDS, EC, pH, and DO with r value of -0.63, -0.56, -0.10 and -0.31 respectively and turbidity with TDS, EC and pH with r values of -0.44, -0.43 and -0.12 respectively.

Muet Water T&Ds

In MUET water T&DS, intake water is first treated. Coagulation and flocculation is done to remove solids from the intake water. Then water is sent to four sedimentation tanks where suspended solids settle down by gravity. After sedimentation, water is allowed to pass through slow sand filters to clear residual solids from water.

The MUET water T&DS needs upgrading due to increasing number of consumers relying on it. There are also issues of capacity building for developing core competencies such as regulations, water quality standards and monitoring for ensuring continued water supply. MUET water T&DS works through pumping which stops working during load shedding. Thus, there is need of an overhead tank which can maintain requisite pressure and supply once it is filled. Also, chlorination and alum doses are not administered. The treated water after passing through the pipelines also catches some pollutants which show that proper monitoring of water pipelines and corrective measures to avoid contamination during transportation in pipeline network are required. The proposed treatment flow chart is shown in Figure 4.3.



Continuous monitoring

Figure 4.3. Treatment process at MUET water Treatment Plant

Table 4.2.1. Pearson correlation matrix at Intake

	Temperature (℃)	Turbidity (NTU)	TDS (mg/L)	EC (uS/cm)	pH	DO(mg/l)
Temperature (℃)	**1**					
Turbidity (NTU)	**0.786164909**	**1**				
TDS (mg/L)	**-0.871495201**	**-0.811177318**	**1**			
EC (uS/cm)	**-0.846232981**	**-0.812840743**	**0.99699626**	**1**		
pH	**-0.246290983**	**-0.296914617**	**0.354281459**	**0.360322268**	**1**	
DO(mg/l)	**-0.035648059**	**-0.013223526**	**0.269392412**	**0.250909999**	**-- 0.4727575**	**1**

Table 4.2.5 Pearson correlation matrix at Post-Filter Storage Tank

	Temperature (℃)	Turbidity (NTU)	TDS (mg/L)	EC (uS/cm)	pH	DO(mg/l)
Temperature (℃)	1					
Turbidity (NTU)	0.739111087	1				
TDS (mg/L)	-0.694987163	-0.746305616	1			
EC (uS/cm)	-0.628052631	-0.720415581	**0.990728894**	1		
pH	-0.473241976	-0.66661762	0.515450162	0.511789041	1	
DO(mg/l)	-0.278983894	-0.131756875	0.053639387	0.0347218	0.197572	1

Table 4.2.8 Pearson correlation matrix at IWREM

	Temperature (℃)	Turbidity (NTU)	TDS (mg/L)	EC (uS/cm)	pH	DO(mg/l)
Temperature (℃)	1					
Turbidity (NTU)	0.311046904	1				
TDS (mg/L)	-0.631971145	-0.442357654	1			
EC (uS/cm)	-0.56500652	-0.435670606	**0.986694932**	1		
pH	-0.104931759	-0.121434333	0.2116554	0.214554753	1	
DO(mg/l)	-0.318629924	0.219385973	-0.395093035	-0.435897877	-0.104073345	1

Table 4.1: Statistical analysis of various parameters at MUET water T&DS

Sampling Locations	Coordinates		Temperature (°C)		Turbidity (NTU)	pH	TDS (mg/L)	Electrical conductivity (µs/cm)	DO (mg/L)
	Latitude	Longitude							
WHO limit	-	-	>25ºC		< 5 NTU	6.5-8.5	< 500 mg/L	600-800 µs/cm	not < than 4 mg/L
Intake	25°23.528	68°17.065	Max	38	908	8.5	949	1317	8
			Min	18.9	10.2	6.5	129.4	199.0	5
			Mean	26.8	195.7	8.04	442.6	652.2	6.59
			St.dev*	5.19	283.3	0.41	267.4	382.8	1.05
Entry Coagulation	25°23'36.34	68°15'47.99"	Max	34	940	8.5	955.0	1370	10.5
			Min	17	11.1	7.7	129.5	199.2	7.2
			Mean	26	156.0	8.1	466.4	679.9	8.81
			St.dev	5.46	258.8	0.20	253.5	364.4	1.10
End Coagulation	25°23'36.86"	68°15'48.16"	Max	33	989	8.7	1033.5	1464	8.1
			Min	17	9.53	6.8	130.0	200	5.5
			Mean	26	154.5	8.2	450.4	658.1	6.76
			St.dev	5.42	273.9	0.45	260.4	368.7	0.84
Slow Sand Filter	25°23'38.77"	68°15'2.39"	Max	31	351	8.6	916.5	1284	10.2
			Min	16.2	15.5	7.1	120	184.6	3.3
			Mean	22.8	58.9	8.32	530.7	761.2	7.2
			St.dev	4.54	81.5	0.28	216.8	309.2	1.70
Post-filter Storage Tank	25°23'40.24"	68°15'53.23"	Max	36	465	8.5	832	1161	10.7
			Min	16.2	23.5	6.8	120	184.6	6.4
			Mean	24.81	128.4	8.1	433.1	616.8	8.93
			St.dev	5.24	144.3	0.42	241.1	331.9	1.51
MUET Water Storage Tank	25°24.349	68°15.683	Max	36.00	419.00	8.60	832.00	1178.00	8.40
			Min	16.90	16.80	6.70	104.39	160.60	4.40
			Mean	26.39	119.51	8.12	397.51	590.27	7.00
			St.dev	4.71	127.67	0.44	245.17	358.32	1.25
EE department (Tap Water)	25°24.042	68°15.356	Max	39.00	166.00	8.60	767.00	1128.00	10.20
			Min	18.40	4.61	7.20	138.20	212.62	5.30
			Mean	28.40	35.95	8.21	396.85	606.26	8.82
			St.dev	5.09	44.12	0.31	200.97	305.23	1.15
IWREM (Tap Water)	25°24.924	68°15.608	Max	43.00	473.00	8.60	806.00	1255.00	10.10
			Min	20.30	10.50	7.10	29.06	44.70	5.60
			Mean	30.85	64.27	8.09	413.40	635.88	8.32
			St.dev	6.44	101.51	0.30	232.31	368.31	1.13

St.dev* = Standard deviation

Conclusion

This study analyzed the quality of water being supplied to various consumers in MUET ranging from students, faculty and residents through its water Treatment and Distribution System (T&DS) by taking into account seasonal variations. This study also checked the performance of the MUET T&DS. The samples were analyzed for temperature, turbidity, TDS, EC, pH, DO and total coliforms. The results showed that current water treatment system does not offer adequate disinfection as was proved from positive results obtained after analyzing samples for Total coliforms. The average values of temperature are exceeding WHO limit at all locations except slow sand filter and post filter storage tank. The average values of turbidity at all selected locations is exceeding limit set by WHO i.e. 5 NTU. From all locations turbidity is maximum at intake (KB feeder) which shows source as full of turbid material. The mean of pH values at few locations is above 8 but it still lies within standard limit i.e. 6.5-8.5. Total dissolved solids content at slow sand filter is exceeding WHO limit i.e. 500 mg/L. However it is below limit at all other locations. Dissolved oxygen in water is considered good when it is above 4 mg/L as set by WHO, at all selected locations DO is above 4 mg/L. The results show that there is need of comprehensive monitoring along with efforts to ensure compliance with standards set by WHO. Total coliforms were present in the water even after treatment which showed microbial contamination. These results show that there is need of improvement in water treatment system, and comprehensive monitoring along with efforts to ensure compliance with standards set by WHO.

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ASSESSMENT OF HEAVY METALS CONTAMINATION IN DRINKING WATER TREATMENT PLANT MUET JAMSHORO

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ABSTRACT

In the present study, we have determined the trace heavy metals such as zinc, copper, iron and chromium (Zn, Cu, Fe and Cr) in different stages of water quality such as source, MUET water treatment plant and distribution system. The water samples were coded as S1 (KB Feeder / Intake), S2 (Sedimentation Tank Outlet), S3 (Post filtration), S4 (MUET Storage) and S5 (IWRM), respectively. The pre-concentration of water samples were analyzed by atomic absorption spectroscopy. The average values of Fe, Zn, Cr and Cu were determined in different water quality samples coded as S1 (261.9, 7.983, 1.8, 2.125µg/L), S2 (181.6, 13.61, 1.225, 1.833µg/L), S3 (309.4, 2.233, 0.667, 1.333µg/L), S4 (410.2, 6.325, 1.158, 1.6µg/L) and S5 (329.2, 6.791, 1.966, 3.7µg/L), respectively. The data obtained in this study were compared with reference to world health organization (WHO) water quality guidelines and indicated moderate-to-high pollution by some trace metals. The environmental pollution caused by the trace heavy metals is a long-term and irreversible process. The concentration of Zn, Cu, and Cr are under WHO and national environmental quality standards (NEQS) guide line limits but average Fe values exceeds the WHO and NEQS guide line limit. The average concentration of Fe was exceeded in sample location S3, S4 and S5 from 309.4, 410.2 and 329.2µg/L) as compared to NEQS and WHO guide line limits.

Keywords

KB Feeder, Trace heavy metals, Water quality

Introduction

In recent years, metal contamination in the aquatic environment as well as for human beings has attracted global attention owing to its environmental toxicity,

abundance and persistence [1, 2, 3]. Large quantities of hazardous chemicals especially heavy metals have been released into rivers worldwide due to global rapid population growth and intensive domestic activities, as well as expanding industrial and agricultural production [4, 5, 6]. Heavy metals are natural constituents of the earth's crust. Geological conditions of weathering and erosion takes trace elements from sediments to contaminate the water source [7], other ways for contamination of water are the effluent deposition by disposals of pre-treated and post-treated liquids [8], deposition due to atmospheric conditions [9], Terrestrial run-off [10], Pesticides and fertilizers [11] because of the extensive use of heavy metals; the evaluation of the water pollution with those materials is an important task of environmental researchers. Rivers in urban areas have also been associated with water quality problems because of the practice of discharging of untreated domestic and industrial waste into the water bodies which leads to the increase in the level of metals in river water [12, 13, 14] During transport, heavy metals may undergo numerous changes in their speciation due to dissolution, precipitation, sorption and complexation phenomena [15], which affect their behavior and bioavailability.

The European community mainly focuses with the highest concern for eleven metals namely arsenic, chromium, cadmium, copper, cobalt, lead, manganese, tin, nickel, mercury and thallium. The occurrence of metals is natural in environment, the change in level of piousness that is the less level causes the fulfillment of need to the balance of planet and with more level causes the harmful effects on the human, animals, aquatic life, plants and forests [8]. The metals enter into the aquatic environment by geologic erosion of milieu, the deposition through atmosphere, through the urban storms, water runoff, landfill, mining of coal and ore, chemical weathering of minerals naturally introduce into water , soil leaching, due to industrial effluents, anthropogenic activities and domestic sewage [13].

Heavy metals act as contaminates for drinking water if not removed by water treatment plant, waste water and industries are most hazardous for aquatic and human beings because of their high solubility in aquatic environments and also can be absorbed by living organisms. When they enter the food chain, large concentrations of toxic metals may accumulate and causes several health serious disorders [14], including nervous system damage, organ damage, cancer, reduced growth and development and in severe cases, death.

The effect of organic and inorganic pollutants depends on the degradability of the constituents, organic pollutants easily decompose by chemical or biological phenomena and form less affecting particles whereas inorganic particles are naturally not degradable, inorganic particles remains in elemental form [7]. In present study, Pakistan, especially in Sindh, district Jamshoro a very few studies were reported on water quality in reverence of heavy toxic metals in drinking, raw water. Therefore, it needs on urgent basis for the determination of toxic metals in water treatment plant and finally to make a water quality as WHO standards.
water treatment plant and finally to make a water quality as WHO standards.

Experimental Studies

Sampling

Description of the Study area and Geographical Location of Experimental Site

The Indus River plays an important role as one of the key water resources for economy of Pakistan [7]. The Indus River on the basis of annual discharge and length ranked as world twenty third biggest river and thirty first longest River having length 11, 65,500 square km before flowing into Arabian Sea [4]. The Indus River sharing water to two lakes such as Keenjhar and Haleji located to nearby its bank, and finally ends into Arabian Sea [7].

Figure 1 Map showing flow of Indus River, Pakistan.

The flow of the Indus River is highly variable with high flow in summer and low flow in winter season, from July to September the peak flow causes floods and transportation of silt and sediments. The Kotri barrage is located at the downstream of river Indus, the upstream of river Indus water is polluted through the discharge of domestic, industrial and agriculture waste, the quality of water deteriorate with the high discharges of polluted matter into the river. The Kotri barrage is near about 200 km at the distance from Arabian Sea, its length 3000 feet and designed for 24500 m3/s maximum flow [7]. The Karli Baghar Feeder starts at the right side of the Kotri barrage, and KB feeder supplies water to Mehran Water Treatment Plant.

Before consumption of water to Mehran water treatment plant it needs various treatment processes including coagulation, sedimentation, rapid sand filtration and disinfection by improving drinking water quality parameters is exposed to various treatment processes includes the adjustment of pH, hardness, addition of chemicals coagulant and to control metal corrosion, adjustment of alkalinity, carbon adsorption or filtration, slow sand and membrane filtration and supplemental fluoridation. [15].

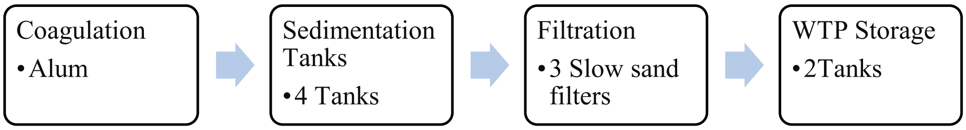

Figure 2 Mehran University Water Treatment Train.

In the MUET campus, Current water supply system is designed to handle a volume of 1 million Gallon per day (MGD) throughout whole year, except two to three weeks period in the winter, when KB feeder is closed for maintenance. The small and big water storage tanks are built in the campus, three main storages are also installed, and two at the treatment plant facility and another one at Mehran University near foreign faculty, all tanks are used for storage and distribution of water in the university premises.

In Pakistan, Sindh (Jamshoro) the greater extent of the fresh water ecosystem is affected by the bad water quality and heavy metals pollution. This study of Mehran university water treatment plant recently has been raised attention to public concern due to its water pollution. Recently, there is no scientific research regarding heavy metal an issue in this study area has been conducted so far. Therefore, the objective of this study is to assess the monthly basis of heavy toxic metal pollution status of the MUET water treatment plant by estimating in water and sediments and by assessing water quality index.

Sampling Locations

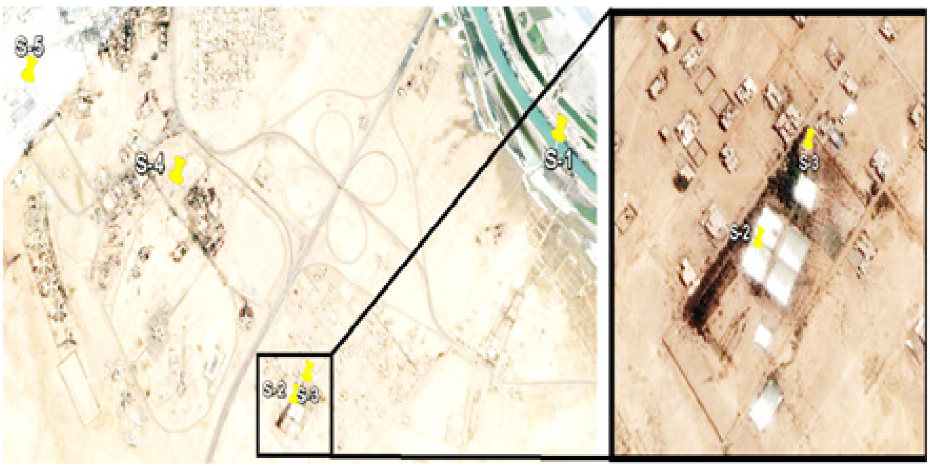

Figure 3 Map of water treatment plant with sampling locations

In the following Table 1 shows the water samples locations from source and WTP MUET Jamshoro and the total five (5) number of sampling locations (sites), coordinates, description, point code were selected for samples analysis, such as S1 (KB Feeder / Intake); S2 (Sedimentation Tank Outlet); S3 (Post filtration); S4 (MUET Storage) and S5 (IWRM). Sample Collection started from 15, June and ended to 15, December 2016, with seasonal variation samples collected time between 8:00 am to 12:00pm.

Table 1 Description of sampling locations.

Point code	Locations	Coordinates	Description
S-1	KB feeder/ intake	25° 23' 31.492" N 68° 17' 4.441" E	Site-1 sampling at KB Feeder, it is Located about 7Km downstream of Kotri Barrage. It is raw water source, i.e. the source supplying water to MUET treatment plant and it will reflect the quality of the source
S-2	Sedimentation tank outlet	25° 23' 39.476" N 68° 15' 48.946" E	Site-2 Sedimentation tank outlet, Primary treatment is effective or not (coagulation & sedimentation tank), to check quality of water, are pollutants being removed or not?
S-3	Post filtration	25° 23' 39.972" N 68° 15' 53.546" E	Site-3 Post filtration, to ensure that the slow sand filters are working?
S-4	MUET storage	25° 24' 20.588" N 68° 15' 51.829" E	Site-4 Distribution tank/ MUET storage near Foreign Faculty Hostel, it is located about 1.4Km from S-3, to check contamination in conveyance from S-3 to S-4.
S-5	IWRM	25° 24' 54.724" N 68° 15' 36.403" E	Site-5 Integrated water Resources Management department, it is located about 1.4Km from S-4, to ensure water quality at distribution ends

Chemical Analysis

Water Sample Preservation

The samples will be collected in 500ml pre-sterilized polyethylene plastic bottles, previously soaks in 10% nitric acid for 24 hours and rinsed with Distilled water. The bottles will be handled carefully to avoid trapping air bubbles. The samples of water are sealed with polyethylene plastic double zip lock bags to avoid from contaminations, having specific codes, labeled and keep to store in refrigerator (4°C) for further analysis.

Water Sample Preparation

For pre-concentration of liquid samples, took the 100-200 ml volume of sample and add the 10 ml of concentrated nitric acid and then digest on the hot plate at 90oC. After cooling, the obtained semi-dried mass is filtered through a Whatsman No. 42 filter paper, diluted to desired volume (100/50mL) with the help of de-ionized water and finally to analysis the heavy metals by flame atomic absorption spectrometry (FAAS/ETAAS) (AI, 1200).

Instrumentation

Parameters And Standard Analytical Methods For Analysis

Heavy Metals such as (Fe, Cu, Zn, Cr) were analyzed by electro thermal atomization absorption spectrometry using standard method (APHA 3111A). The standard solutions were prepared of 2ppm, 4ppm, 6ppm, 8ppm and 10ppm, respectively. The standard solutions were run before samples in flame atomic absorption spectroscopy (FAAS). The calibration curve was prepared to run the samples from 2,4,6,8 and 10ppm on FAAS. After running standard solutions, the sample was run and concentration of metals is calculated from calibration curve automatically by AAS.

Quality control

The analytical data quality was guaranteed through the implementation of laboratory quality assurance and quality control methods, including the use of standard operating procedures, calibration with standards, analysis of reagent blanks, recovery of known additions and analysis of replicates. All analyses were carried out in triplicate.

Results and Discussion

The trace metal concentration of Fe, Cr, Zn and Cu were analyzed in the KB Feeder, water treatment plant, distribution network. The concentrations of all the heavy metals are shown in figure 2. The analysis results for water samples are presented separately for each sampling point. The results show the relationship between the parameters at each location. The study suggested that the some trace metal concentration in River Indus is more and the water can affect the marine life and human life [4, 14]. The water used in agriculture can bio-accumulate trace metals into plants and trees and can affect consumers of agriculture products as shown in Table 2.

Table 2 Average concentrations (µg/L) of Trace Metals with WHO Guide line limits.

Sample Station	Avg. Fe (µg/L)	Avg.Zn (µg/L)	Avg. Cr (µg/L)	Avg.Cu (µg/L)
S1	*261.9*	*7.983*	*1.8*	*2.125*
S2	*181.6*	*13.61*	*1.225*	*1.833*
S3	*309.4*	*2.233*	*0.667*	*1.333*
S4	*410.2*	*6.325*	*1.158*	*1.6*
S5	*329.2*	*6.791*	*1.966*	*3.7*
WHO Limit	*300*	*3000*	*50*	*2000*

It is very important to identify the relationship between the presence of heavy metals in drinking water and the prevalence of renal failure, liver cirrhosis, hair loss, and chronic anemia diseases. The prevalence of these diseases was markedly increases in the last few years due to air pollution, water pollution, and hazards over uses of pesticides in agriculture. Trace amounts of metals are common in water, and these are normally not harmful to our health. In fact, some metals are essential to sustain life. The average concentration of iron (Fe) in samples is 298.9µg/L. The concentration of Fe ranged from 24 to 415µg/L, this high range exceeds the WHO and NEQS guide line limits. The concentration of iron at sample location S3 to S5 ranges the higher concentration (309 to 410µg/L) as compared to NEQS and WHO Guide line must be present for normal body functions.

Zinc (Zn) is important trace metal found in potable water and all foods. Drinking water containing Zn above 3000µg/L is not acceptable to consumers [4, 10, 16]. The observed value for Zinc ranges 0.57 to 28µg/L. copper, iron, zinc are needed at low levels as catalysts for enzyme activities. Copper is a fundamental nutrient and a drinking-water contaminant. For controlling the algae in surface water Copper sulfate pentahydrate is added [15]. The Cu concentration is very low in the samples. Cr is widely present in earth's crust. Its source of intake is majority food. The average Concentration of Cr in the water sample was quite low. In the round one Cr was not detectable in most of the sites. The average concentration of Cr observed is 1.363µg/L. Chromium is a specific pollutant providing evidence of industrial pollution like dyeing or paint operations.

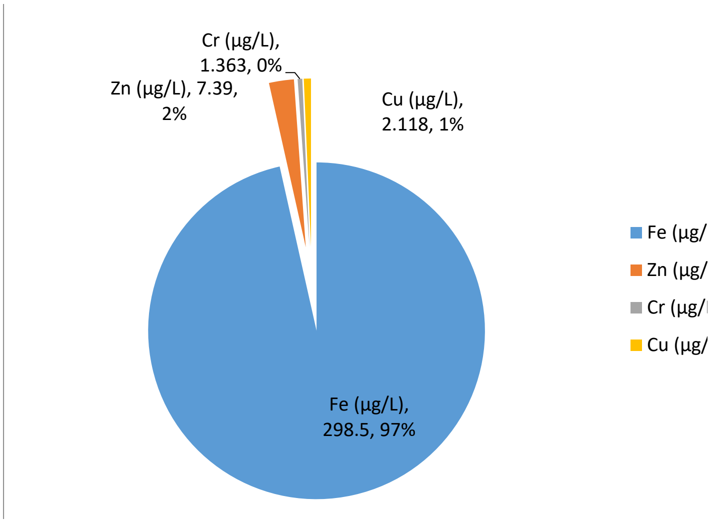

Figure 3 Observed data of heavy trace metals from MUET water treatment plant.

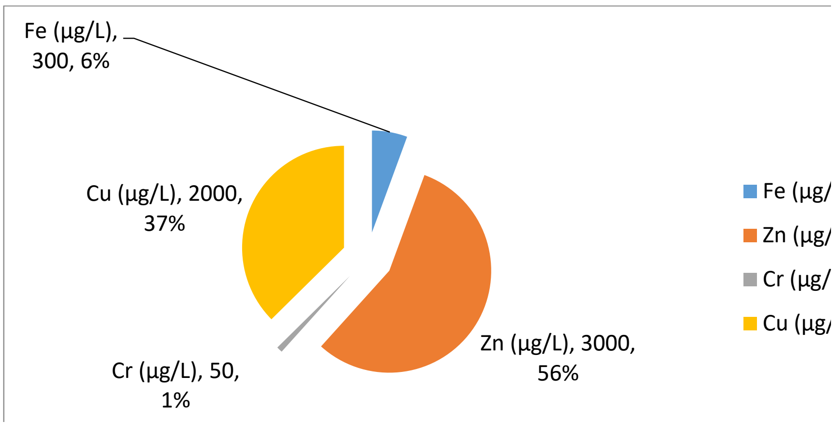

Figure 4 WHO guide line of heavy trace metals (Fe, Cu, Zn and Cr).

Table 3 Comparison data of heavy metals with observed and WHO standard limits.

Metals	**Observed**	**WHO limits**
Fe (µg/L)	298.5	300
Zn (µg/L)	7.39	3000
Cr (µg/L)	1.363	50
Cu (µg/L)	2.118	2000

Conclusion

In this study, the multi-heavy metals determination of Fe, Zn, Cr and Cu in MUET drinking water treatment plant with different sample locations such as KB feeder/intake, sedimentation tank outlet, post filtration, MUET storage and IWRM. These sample locations were coded as S1, S2, S3, S4 and S5, respectively. The samples were collected by seasonal variations from 15th June 2016 to 15th December 2016 (summer, fall and winter) between 8:00am to 12:00pm with Pakistan standard time. The multi-heavy metals were determined by using FAAS. The average values of Zn, Cr and Cu in all samples (S1 to S5) were in the range of WHO and NEQS guideline limits but the highest Fe values (309.4, 410.2 and 329.2μg/L) was found in S3 (post filtration), S4 (MUET storage) and S5 (IWRM). The average concentration of Fe in S3, S4 and S5 samples were exceeded from the WHO and NEQS guideline limits. Heavy metals acts as contaminates for drinking water if not removed by water treatment plant, waste water and industries are most hazardous for aquatic and human beings. As a result, more consideration must be paid to the health risks of heavy metal contamination in drinking water. In the meantime, the results put down a basis for avoiding heavy metal toxicity in humans around from MUET drinking water treatment plant.

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WATER QUALITY ASSESSMENT OF KOTRI BARRAGE AND ITS CANALS

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ABSTRACT

River Indus and its canals provide water for various purposes such as agriculture, drinking, domestic, commercial and industrial uses. But, increased industrialization and urbanization have resulted in higher levels of heavy metals in these water sources. Also, other pollutants and hazardous chemicals are being continuously discharged in the Indus River System and pollute it. This study aims at examining the water quality at Kotri Barrage from where four canals off-take which is source of water supply to millions of people of lower Sindh, including Hyderabad, the second largest city of Pakistan. Realizing the need to assess water quality of these canals, this study was undertaken to examine the water quality at upstream of Kotri barrage in the year 2016-17. The results of the analysis showed that toxic and heavy metal concentrations in water in July and August 2016 were then compared with National Organization i.e. WHO Standards of water. Pb, Cu and Zn concentrations in water were higher than WHO permissible limits. Similarly, water analysis results of 2017 of heavy metals viz. Cd, Fe and Mn were comparatively higher during non-monsoon period. Remaining heavy metals were within the permissible limits because of high dilution factor in monsoon season. The effort of this study can be utilized for monitoring the effects of pollutants over a period of time and thus would help in controlling these contaminants. This study has thus made a baseline on water quality, which may contribute in analyzing the Indus water basin model in future.

Keywords

Heavy metals, water, water quality standards, pollution, discharge, contamination

Introduction

Water is the most abundant yet the scarcest resource impacting the globe [4]. Ninety eight percentage of the earth's surface is covered with water, but most of it is saline. Only 2 % of it is freshwater and even much of that is frozen in the polar caps. Out of this, only half is available for the use of 7.6 billion people (and rapidly multiplying). Most of this is made accessible from rivers, lakes and subsurface aquifers. The pressures on this water from different interest groups, users and
polluters cannot be overstated. Planning and conservation of freshwater is paramount [5].

The River Indus is important for the nearly 160 million people of Pakistan and irrigates 80% of its 21.5 million hectors of agricultural land. The River Indus Basin spans portions of 4 countries (Pakistan, Afghanistan, India and China) in an area that is more than 30% arid, and much drier than the adjacent to the Ganges River Basin. The watershed is one of the rich biodiversity, specifically where it is open to the Arabian Sea. The Indus River Delta is an important region for water birds and is an extremely productive area for freshwater fauna.

This research paper focuses on improving the quality of fresh water in Kotri Barrage, built over the River Indus in Jamshoro, Sindh Province, Pakistan. There are three barrages that come from River Indus namely Guddu, Sukkur and Kotri [1]. Kotri Barrage was built on River Indus in 1955, which supplies water to many cities [12] and feed agriculture in the lower Indus area [1]. The Barrage was designed to pass a thoroughgoing flow of about 875,000 cusecs (24,780 cumecs). It is a water source of about more than 25 million people and cause of water supply for an area about 2.78 million acres (1.126 million hectares) for industrial, domestic and irrigation purposes. From Kotri barrage, four canals are off-taking [12]. A canal named as Kalri Baghar is the leading source of supplying water to Karachi from Kotri Barrage. From right bank, there is only one canal known as Kalri baghar nourishes a very famous Keenjhar Lake, which performs as a reservoir for Karachi city [1] and the remaining left bank canals includes Phuleli, Pinyari and Akram Wah (linned channel) canals [12]. Drinking water here is under a tremendous amount of stress and is filled with contaminates including heavy metals, bacteria, viruses, nitrates and salts from industry, agriculture. Other sources including these contaminants, have found their way into the water supply because of insufficient treatment and disposal of waste (both from livestock and humans) and miss use of limited water resources and industrial discharges.

The contaminants in the water cannot be adequately removed by users without access to municipally supplied water which is predominantly located in the poorest communities. It impacts their health and hence ability to work, creating a vicious cycle keeping them from improving their quality of life [1]. Even if sources of anthropogenic contamination were not introduced into the River system, the natural sources also have high levels of metals and other chemicals that are damaging human health [2]. In Bangladesh, for example, it has recently come to light that in groundwater the natural levels of arsenic are producing injurious effects on the population [3].

In this research, eighteen water quality parameters i.e., five physical parameters like Temperature, Turbidity, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Total Suspended Solids (TSS) and seven chemical parameters like pH, Dissolved Oxygen (DO), Sulphate, Hardness, Alkalinity, Chloride and Nitrate and six heavy metals such as Lead (Pb), Cadmium (Cd), Copper (Cu), Iron (Fe), Zinc (Zn) and Manganese (Mn) were tested from the collected samples. According to the World Health Organization (WHO) and National Environmental Quality Standards (NEQS) Standard values for Pakistan.

Material and Methods

Study Area

This study was conducted on the River Indus Sindh Province, Pakistan. It is one of the longest rivers in the world, with a length of some 2,000 miles (3,200 km). Its total drainage area is about 450,000 square miles (1,165,000 square km), of which 175,000 square miles (453,000 square km) lie in the ranges and foothills of the Himalayas, the Hindu Kush, and the Karakoram Range; the rest is in the semiarid plains of Pakistan [11]. There are three barrages that come from River Indus namely Guddu, Sukkur and Kotri [1]. Kotri Barrage was built on River Indus in 1955, which supplies water to many cities [12] and feed agriculture in the lower Indus area [1]. The Barrage was designed to pass a thoroughgoing flow of about 875,000 cusecs (24,780 cumecs). It is a water source of about more than 25 million people and cause of water supply for an area about 2.78 million acres (1.126 million hectares) for industrial, domestic and irrigation purposes. From Kotri barrage, four canals are off-taking) [12]. A canal named as Kalri Baghar is the leading source of supplying water to Karachi from Kotri Barrage. From right bank, there is only one canal known as Kalri baghar nourishes a very famous Keenjhar Lake, which performs as a reservoir for Karachi city [1] and the remaining left bank canals includes Phuleli, Pinyari and Akram Wah (linned channel) canals [12].

Sampling Sites

About 24 water samples were collected from 5 different sampling locations i-e; L1 upstream of Kotri Barrage, L2 Akram Wah, L3 Pinyari Canal, L4 Phuleli Canal and L5 Akram Wah (Lined Channel) of River Indus in July and August, 2016 (Monsoon period) and March and April, 2017 (Non-Monsoon period) as shown in Figure 1. During winter, there is no rainfall, and river water levels decrease; during summer, river water levels increase due to heavy rainfall. Considering the water flow in the studied river, summer season exhibited higher than winter season which can cause the variation of metals concentration in water. Water samples were filtered (0.45 µm filters) into polypropylene tubes using a plastic syringe (BD Plastipak, 50 mL) for dissolved metal concentrations. Samples were acidified with HNO3 and kept at 4◦C in the dark until analysis. After collection samples were brought to the Environmental Engineering department laboratory, Mehran University of Engineering and Technology, Jamshoro.

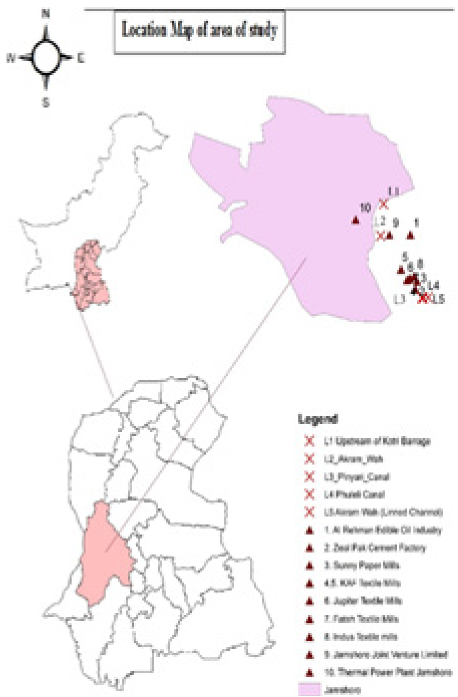

Figure 1: Location of the study in Pakistan and Kotri barrage and its canals where the water samples were taken

Water Quality Parameters

In this research, eighteen water quality parameters i.e., five physical parameters like Temperature, Turbidity, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Total Suspended Solids (TSS) and seven chemical parameters like pH, Dissolved Oxygen (DO), Sulphate, Hardness, Alkalinity, Chloride and Nitrate and six heavy metals such as Lead (Pb), Cadmium (Cd), Copper (Cu), Iron (Fe), Zinc (Zn) and Manganese (Mn) were tested from the collected samples. According to the World Health Organization (WHO) and National Environmental Quality Standards (NEQS) Standard values for Pakistan.

Quality Control

The analytical data quality was guaranteed through the implementation of laboratory quality assurance and quality control methods, including the use of standard operating procedures, calibration with standards, analysis of reagent blanks, recovery of known additions and analysis of replicates. All analyses were carried out in triplicate, and the results were expressed as the mean.

Results and Discussions

Physico-Chemical Parameters

The physico-chemical parameters of the water column such as dissolved oxygen (DO), pH, temperature etc. are presented in Table 1A and Table 1B. The physicochemical parameters are very important because they have a significant effect on the water quality. Further-more, aquatic life also suffers due to degradation of water quality. Among the external factors temperature is one of the most important factors which influence the aquatic ecology [7]. The values of temperature were ranged from 30.8oC to 34.6oC and 27.1oC to 30.4oC during summer and winter, respectively as shown in Figure 1A (i) and Figure 1B (ii). The mean value of water temperature was not found within the permissible limits set by (WHO, 2004), during summer. The value of Temperature according to WHO 2004 guideline was between 25 and 30oC [8]. The turbidity was higher in monsoon season i.e., 817-911 mg/L and low turbid in non-monsoon period except from location L1. The average pH was 7.89 and 8.11 during summer and winter, respectively as presented in Table 1B. In the present study, the highest hardness 250 mg/L was observed in location L4 i.e., Phuleli canal during non-monsoon where lower hardness 25 mg/L during monsoon was observed in location L1 as shown in Figure 1B(i). Dissolved oxygen refers to the oxygen gas that is dissolved in the water and made available to aquatic life. The solubility of oxygen increases with decrease the temperature [9]. As was expected the highest value of DO was recorded during winter (non-monsoon) season might be due to temperature in this season was low [1]. The dissolved oxygen (DO) was found 7–14.1 mg/L during monsoon period and 4.7–12.9 mg/L in non-monsoon period in Figure 1B (ii). The lowest value of DO was observed during summer that could be due to the less or no rainfall and increase in temperature that lead to decrease in dissolved oxygen results due to the rate of oxygen consumption from aquatic organisms and high rate of decomposition of organic matter. The study reported that a suitable range of alkalinity is 20–300 mg/L for fish [10]. In the present study the alkalinity range was 10-30 mg/L), it indicates that the level of alkaline is a suitable condition. Nitrate and Sulfate were also measured in monsoon and non-monsoon. Nitrate was in the range of 16.25-29.03 mg/L in monsoon and 4.7-10.58 mg/l was measured in non-monsoon. Similarly, in monsoon, Sulfate was 18.4-23.9 range and in non-monsoon sulfate was within the range of 104.8-178.34 mg/L which was within the permissible limit.

Table 1A. Physical water quality parameters at each location of this study

	Temperature		Turbidity		TDS		EC		TSS	
	Mon	Non	Mon	Non	Mon	Non	Mon	Non	Mon	Non
WHO	25◦C		<5 NTU		<1000 mg/L		2000 µs/cm		50 mg/L	
L1	33	32	859	61.6	132.1	410	270	820	1684	47
L2	31	32	911	7.35	129.8	490	260	1000	1570	28
L3	34	27	817	10.5	134.5	630	270	1260	1454	30
L4	32	27	966	9.1	129.8	690	260	1370	1336	28
L5	31	28	934	8.49	130.3	520	250	1030	1596	48

Note: Mon= Monsoon, Non= Non-Monsoon season, respectively

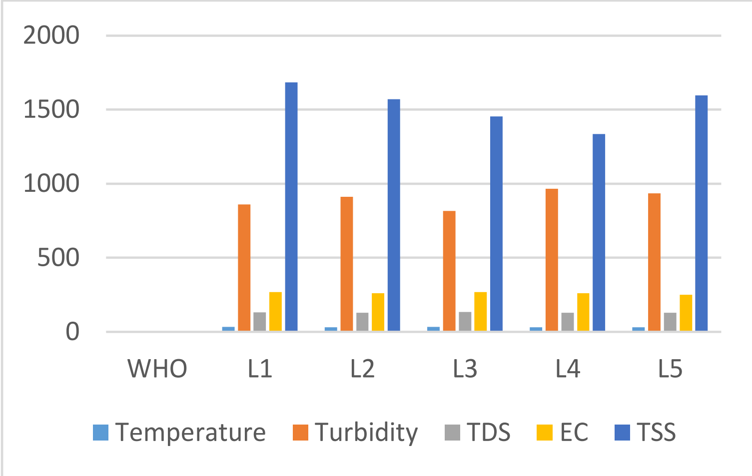

Figure.1A (i) Physical parameters at each location of this study during Monsoon period

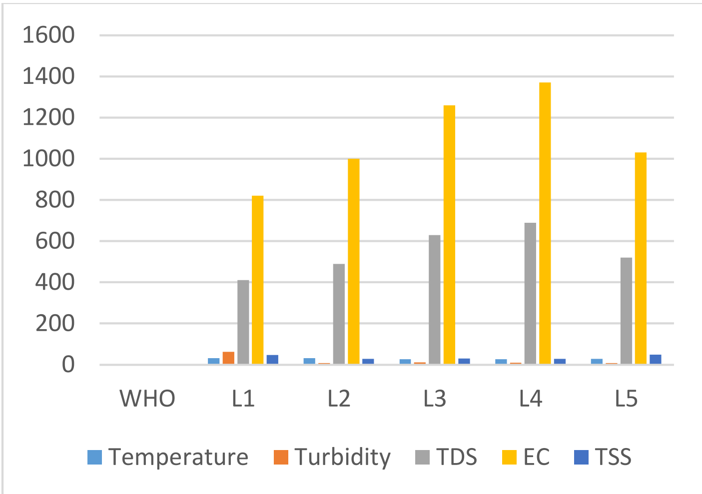

Figure.1A (ii): Physical parameters at each location of this study during Non-Monsoon period

Table 1B. Chemical water quality parameters at each location of this study

	pH		DO		Alkalinity		Chloride		Hardness		Sulphate		Nitrate	
	Mon	Non	Mon	Non	Mon	Non	Mon	Non	Mon	Non	Mon	Non	Mon	Non
WHO	8.5		15 mg/L		200 mg/L		250 mg/L		200 mg/L		400 mg/L		50 mg/L	
L1	7.76	7.85	11	6	____	10	____	80	25	135	18.413	130.492	18.331	13.199
L2	7.96	8.15	14	12.9	____	30	____	120	45	175	22.451	178.34	26.561	11.075
L3	7.9	7.76	7	4.7	____	15	____	170	40	200	23.99	129.46	29.039	7.579
L4	7.46	7.26	8.8	4.9	____	25	____	185	35	250	23.413	123.42	16.252	4.128
L5	7.61	7.58	9	7	____	25	____	130	35	220	23.701	104.778	26.915	5.809

Note: Mon= Monsoon, Non= Non-Monsoon season, respectively

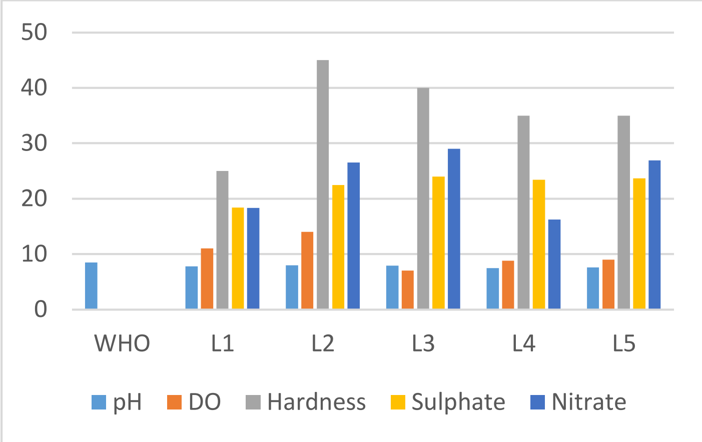

Figure.1B (i) Chemical parameters at each location of this study during Monsoon period

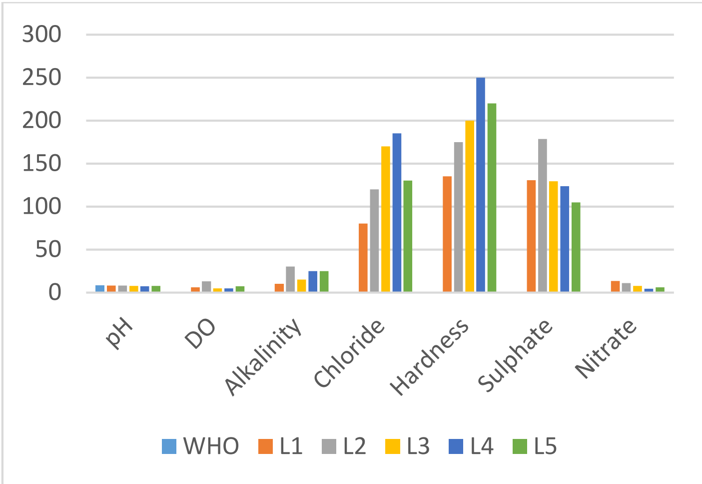

Figure.1B (ii) Chemical parameters at each location of this study during Non-Monsoon period

Metal Concentration in Water

The results of heavy metal concentrations in surface waters are shown in Table 2. The average concentration of studied metals in water followed the decreasing order of: Cd > Cu > Zn > Fe. The mean concentration of Cd in water was observed 0.018 and 0.094 mg/L during non-monsoon season which was much higher than the WHO standard level for drinking water (Table 2).The average concentration of Cu was observed 3.068 and 3.98 mg/L during monsoon season in Figure 2(i). The average concentration of Zn was higher in monsoon season (4.02 mg/L) than that in non-monsoon (2.35 mg/L) in Figure 2(ii), concentration in monsoon exceeded the WHO standard (3 mg/L) (Table 2). The average concentration of Pb in water was 0.0242 mg/L during monsoon season, which was higher than the drinking water quality standard. Almost all the heavy metals especially Cr and Cd greatly exceeded the limit for safe water, indicated that water from this river is not safe for drinking and/or cooking. The metals in water were seasonally varied, where winter season exhibited higher than summer (Table 2). The lower concentration of heavy metals during summer might be due to the dilution effect of water [2].

Table 2. Heavy metal concentration (mg/L) in water sample of each location in this study

	Cd		Cu		Zn		Fe		Pb		Mn	
	Mon	Non	Mon	Non	Mon	Non	Mon	Non	Mon	Non	Mon	Non
WHO	0.003 mg/l		2 mg/l		3 mg/l		0.3 mg/l		0.01 mg/l		0.5 mg/l	
L1	0.012	0.161	-0.362	3.982	4.02	0.521	0.764	1.409	-0.892	0.01894	0.462	0.026
L2	0.002	0.139	-0.308	1.8334	0.8535	2.827	0.021	0.481	-0.963	0.0149	0.056	0.03
L3	0.001	0.132	-0.353	1.236	0.5975	1.085	0.016	1.605	-0.503	0.01674	0.128	0.32
L4	0.046	0.099	-0.345	3.068	0.6353	4.231	0.208	1.059	-0.513	0.0242	0.118	0.29
L5	0.032	0.129	-0.355	3.665	0.482	5.917	0.373	0.628	-0.643	0.01962	0.031	0.312

Note: Mon= Monsoon, Non= Non-Monsoon season, respectively

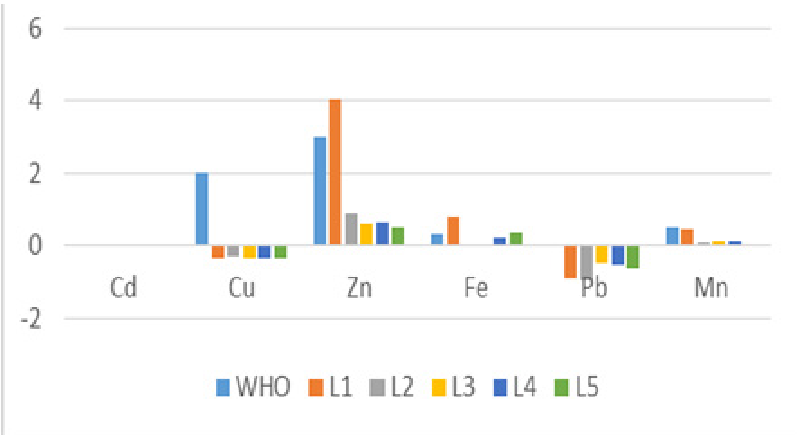

Figure.2 (i) Heavy metal concentration (mg/L) at each location of this study during Monsoon period

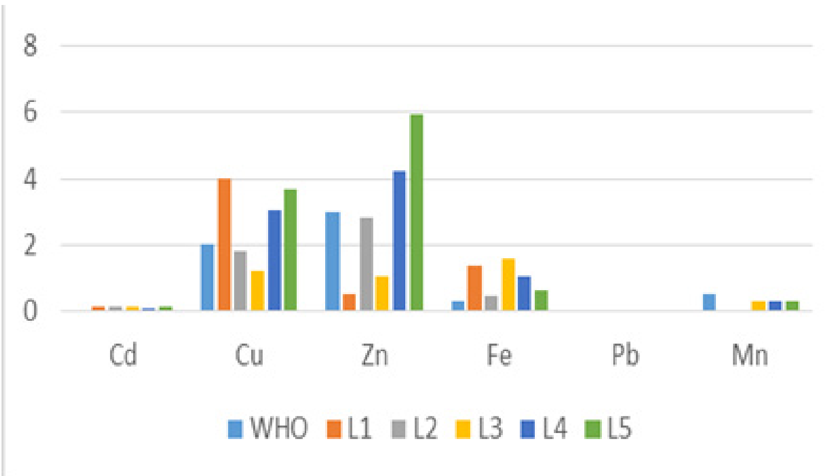

Figure.2 (ii) Heavy metal concentration (mg/L) at each location of this study during Non-Monsoon period

Conclusion and Recommendations

Heavy metal pollution is a major problem for the Indus River basin, Pakistan. In the present study concentrations of Cu, Cd and Pb were higher in Monsoon period and Cu, Pb and Zn were higher in Non-Monsoon period than the safe values which indicated that the river Indus is polluted by studied heavy metals and might create an adverse effect on this riverine ecosystem. Trace and heavy metal concentration in the canal is higher usually during winter season due reduced discharge from Kotri Barrage into canal and reception of low rainfall in the area. The canal water contained highly toxic metals which were beyond the permissible limits of WHO and NEQS for human consumption. Hence, people using canal water, directly or indirectly which are at risk. It is highly recommended that instead of discharging municipal sewage water directly into the Canal Command area, it should be partially treated and then used for propagation of urban agriculture. Regular monitoring of the canal water quality for contamination should be carried out. Awareness programs for local people should be initiated. This study also suggested that point sources of heavy metals in the water should be closely monitored; improvement of conditions and industrial effluent and domestic sewage discharge should be reduced.

Acknowledgment

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GROUND-WATER QUALITY IN ISLAMKOT AND MITHI TALUKAS OF DISTRICT THARPARKAR (DESERT REGION), SINDH PAKISTAN

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ABSTRACT

Assessment of groundwater quality for crop use appeared to be very essential for management and utilization of precious natural water resources. This study reports the quality of 53 hand pumps located in the most remote areas of desert region, viz. Islamkot and Mithi talukas of district Tharparkar. The water samples were collected during April, 2016 (just before the start of rainy season). The water samples were analyzed for EC, pH, CO_3^{2-}, HCO_3^-, Cl^-, Ca^{2+}, Mg^{2+} and Na^+ concentration. The sodium adsorption ratio (SAR) and residual sodium carbonates (RSC) were estimated using their respective formula. The categorization of water samples on the basis of their salt content clearly revealed that the water bodies of majority (65%) of areas were hazardous, while 25% areas were marginal. It was seriously very alarming to know that only 11% water bodies of the area under study had useable irrigation water. Contrarily, on the basis of SAR and RSC the majority (89% and 77% respectively) of water bodies were found to be free from the sodicity hazard. The study concluded that salinity, and not sodicity was the major threat to the area under irrigation through these water bodies. It is, therefore, suggested that the salinity tolerant crops and their genotypes may be used in this area.

Keywords

Groundwater quality, desert area, Tharparkar

Introduction

Desert area Tharparkar is southern district of Sindh province that spread over 19,638 Sq Km, bordered to the east and south by India, in the west side Badin district and in north Mirpurkhas & Umerkot districts. The climatic condition of this area is mostly arid and semi-arid. The average annual rainfall is less than 125mm. Water is one of the natural resources for the life of all living organisms. Fresh water resources are limited even for drinking purpose in the area, however agricultural crops are totally depends upon precipitation and due uneven amount and distribution of rainfall, farmers could not confirmed for getting yield from crops. Because of that problem other resource like groundwater can be used for irrigation purpose according to its quality criteria. Almost all waters contain dissolved salts; however the quality of water depends on the composition and concentration of ions present in it (Rowell, 1994). It is very much critical to recognize the changes in strategies of water suitability for long term productivity of crops [4]. Quality of ground water assessed by different scientists in Nangarparkar talukas of Tharparkar district, they reported that the 27% and 23% of water samples were saline and sodicity hazardous respectively [6]. Dissolve proportion of salt generally lower in surface water as compare to groundwater, because of its direct interaction with geological materials. It has been reported that the low quality of groundwater of Pakistan mainly due to available or more soluble salt within it [7]. According to the recent studies that the ground water contains high concentration of salt and sodium that use for irrigation purpose causes soil salinity or soil sodicity [1]. Whereas some waters are suitable for irrigation purpose if it contain salt below the hazardous level [11]. This study aimed on the assessing quality of groundwater according to the usability for indigenous crops of the area.

Materials and Methods

Water sampling

Populous villages of two taluka of district Tharparkar i.e. Mithi and Islamkot, were selected for this study. From the selected 53 locations (25 of mithi taluka and 28 of Islamkot taluka), sampling of groundwater from 52 hand pumps and 1 Tube well (Khario Nara) was done and analyzed through the suggested methods [5] and depth of water pumps were also noted (Table 1). that was in the range of 60-250ft Collected samples were transported to the laboratory of bio-saline, department of soil science, Sindh Agriculture University (SAU), Tandojam for further analysis.

Table 1. Depth of water bodies in taluka Mithi and Islamkot

Taluka Mithi		
Site#	**Name of Village**	**Depth (ft)**
1	Mithi (Kewal colony)	170
2	Mithi (Shevlal colony)	180
3	Mithi (North Colony)	180
4	Mithi (Rangir Marli)	175
5	Pabuhar (Menghwar paro)	130
6	Pabuhar (Udhecha paro)	135
7	Kak juneja	180
8	Malanhore Khanji	205
9	Malanhore Khanji-2	170
10	Hemasar-1	200
11	Hemasar-2	170
12	Hemasar-3	175
13	Hothiar	165
14	Saatar Kolhi	190
15	Tabho menghwar	200
16	Tabho menghwar	205
17	Abdulah-ji-dhani	130
18	Pabe jo tar	220
19	Mithario Bhatti (Thakar Paro)	225
20	Mithario Bhatti (Menghwar Paro)	240
21	Mithario Bheel	135
22	Bhope jo tar	175
23	Bughar	190
24	Nauhonto	100
25	Khario Nara	250

Table 1. Depth of water bodies in taluka Mithi and Islamkot

Taluka Islamkot		
26	Borli Mosepota (Qabool Paro)	150
27	borli Mosepota (Jummon Paro)	160
28	Wadhan (Sawan Paro)	80
29	Ghoralasayo	85
30	Aakali	90
1	Doonjh (Aqib paro)	90
32	Doonjh (Jamal-din Paro)	85
33	Shurab Wasaipota	130
34	Khankhanyar Bajeer	160
35	Lakhi Tobho	110
36	Dabho Najar	100
37	Misri Memon	200
38	Siranghoo	180
39	Warvai	185
40	Mitharaoo Chhuto	160
41	Nau-tar	170
42	Nikno	180
43	Areri	60
44	Vee Hingorja	170
45	Bhatian je veri	100
46	Joglahar	175
47	Joglahar	190
48	Borili Tarai	160
49	Jogi Marhi	200
50	Banbhanio Bheel	250
51	Thario Halepota	200
52	Dharam	70
53	Chunhar	170

Water analyses

Collected water samples were analyzed for EC_{iw} through digital EC meter (Cyber Scan CON 11, Singapore) and pH using digital pH meter (Lavibond pH110, Singapore). Different soluble cation including Na^+ was analyzed using flame photo meter, whereas total Ca^{2+} and (Ca^{2+} + Mg^{2+}) were determine through complexometric titration with Ethylene Diamine Tetraacetic Acid (EDTA) solution, using 2-3ml of 2 N NaOH solution and about 50mg ammonium purpurate as indicators for calcium and 3-5ml buffer solution (NH_4Cl-NH_4OH) and few drops of eriochrome black-T as indicators for calcium plus magnesium. Whereas for anion like CO_3^{2-}, 1ml phenolphthalein indicator (1%) was added to measured amount of water sample, when developed pink color, it was indicated the presence of carbonates. Methyl orange indicator 0.1% was used for determination of HCO_3^-. Diluted standard H_2SO_4 (0.01 N) was used for titration for presence of carbonates or for bicarbonate analysis. Whereas chlorides were analyzed through $AgNO_3$ (Mohrs's titration) using potassium chromate (K_2CrO_4) 5% as an indicator.

Sodium Adsorption Ration (SAR) and Residual Sodium Carbonate (RSC) were calculated with the formulas give as follow:

$SAR = Na^+/[(Ca^{2+}+Mg^{2+})/2]^{0.5}$

RSC (meq L^{-1}) = $[(CO_3^{2-} + HCO_3^-) – (Ca^{2+}+ Mg^{2+})]$

Water Quality Classification

Irrigation water quality classified on the basis of salinity and sodium hazard (SAR and RSC) to the plant growth and development. Critical limits for these criteria are mentioned in Table 2.

Table 2. Water Quality criteria based on ECiw, SAR and RSC

S #.	Classification	ECiw (dS m^{-1})	SAR	RSC
1	Useable C1S1R1	<1.5 (C1)	<10 (S1)	<2.5 (R1)
2	Marginal C2S2R2	1.5-3.0 (C2)	10-18 (S2)	2.5-5.0 (R2)
3	Hazardous C3S3R3	>3 (C3)	>18 (S3)	>5 (R3)

Statistical Analysis

The data were statistically analyzed for minimum value, maximum value, mean, mode standard deviation and coefficient variance using @Microsoft Excel 2007.

Results and Discussion

Chemical Composition and Properties of Groundwater

Quality of groundwater should be analysis periodically, because the properties of water changes time by time [2, 6, 10]. Water contains many salts in ionic form. The amount of different ions are in variable ranges in various water bodies depend upon the types of soluble minerals interact with it. There are some specific quality parameters of groundwater related to the managing irrigation for better production of crop. Parameters including electrical conductivity (ECiw), pH, different ions, Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonates (RSC) were used to evaluate the water quality for irrigation purposes [3, 8, 12].

Electrical conductivity (ECiw):

Electrical conductivity is the measurement of conductance in water. The conductance increases with increasing of salt concentration in water [9]. The range show (Table 3) of ECiw of groundwater from 0.3 to 13.5 dS $m^{-1}$and 37.7% of samples recoded (Table 4) above the mean (4.9 dS m^{-1}) value. Significant correlation of ECiw with pH, CO_3^{2-}, HCO_3^-, Cl^-, Na^+, Ca^{2+} and Mg^{2+}, however non-significant correlation with SAR and RSC values (Table 6). According to classification WAPDA, 1981, groundwater contain ECiw values less than 1.5 dS m^{-1} have been consider as useable, whereas in the range of 1.5 to 3 dS m^{-1} as marginal and more than 3 dS m^{-1} consider as hazardous for irrigating the crops.

Table 3. Descriptive statistics of the water quality traits

Parameters		**Ranges**	**Mode**	**STD**	**CV**
ECiw (dS m^{-1})		0.3 - 13.5	--	3.2	0.665
pH		7.3 – 9.0	8.0	0.40	0.049
	CO_3^{2-}	0.0 – 4.0	0.0	1.37	1.586
Cations meq L^{-1}	HCO_3^-	1.5 - 11.6	3.1	2.63	0.503
	Cl^-	1.6 – 31.0	3.1	4.68	0.813
	Na^+	4.18 – 21.56	9.46	4.44	0.383
Anions meq L^{-1}	Ca^{2+}	0.39 – 4.32	2.11	0.94	0.583
	Mg^{2+}	0.86 – 9.88	2.16	2.40	0.642
SAR		4.2 - 15.5	--	2.4	0.322
RSC		-7.08 – 8.4	0.03	2.77	3.723

Table 4. Number of water samples for above mean values of ECiw, pH, SAR and RSC

Parameters	Mean value	Number of samples far above the mean value	
ECiw (dS m-1)	4.90	20	37.7%
pH	8.06	11	54.7%
SAR	7.40	29	54.7%
RSC	0.74	16	30.2%

pH

The pH indicates the acidity and alkalinity of groundwater and the normal range of pH is 6.5 to 8.4 for irrigation water [3]. Out of collected groundwater samples 54.7% fall in the normal range and other were above that normal limit. The pH value recorded (Table 3) of groundwater samples were varies from 7.3 to 9.0, whereas average values is 8.06 given in Table 4.

Ions

The dissolve salts (solute) ionized when dissolve into the water body (solvent). Two types of ions have positive and negative charges know as cations and anions respectively. The concentration of major ions (Table 3) of groundwater samples contained CO_3^{2-} in the range of 0.0 to 4.0 meq L^{-1}, HCO_3^-:1.5 to 11.6 meq L^{-1}, Cl^-: 1.6 to 31 meq L^{-1}, Na^+: 4.18 to 21.56 meq L^{-1}, Ca^{2+}: 0.39 to 4.32 meq L^{-1}. Furthermore data indicated that the Na^+ and Cl^- were dominant in water samples. It is clear from the results that NaCl as a major salt available in groundwater samples.

SAR

The quality of irrigation water mainly depends upon the salinity and sodicity parameters. Sodium Adsorption Ratio (SAR) is actually the measurement of potential hazardous of Na^+ over the Ca^{2+} and Mg^{2+}. The SAR values are mostly used for predicting the accumulation of Na^+ in soil that causes the sodicity problem. The minimum SAR (4.0) and maximum SAR (15.5) values were recorded (Table 3) of groundwater samples and mean value noted (Table 4) was 7.4.

RSC

Residual Sodium Carbonates (RSC) is the excess value of $Ca^{2+}+Mg^{2+}$ as of $CO_3^{2-}+HCO_3^-$, that also effect on the quality of irrigation water. The collected samples of groundwater had value of RSC ranges from -7.08 to 8.4 (Table 3) with an average value of 0.74 (Table 4).

Categorization of water samples

The samples of groundwater were categories according to the classification give by WAPDA, 1981 (Table 2). This classification of water for irrigation quality criteria basis on three parameters ECiw (C), SAR (S) and RSC (R) and each parameter divided into useable, marginal and hazardous.

As per WAPDS, 1998 classification of EC values 11.3%, 24.5% and 64.2%, SAR values 88.7%, 11.3% and 0.0% and as of RSC values 77.4%, 18.8% and 3.8% groundwater samples were fall in the categories of useable, marginal and hazardous respectively (Fig 1).

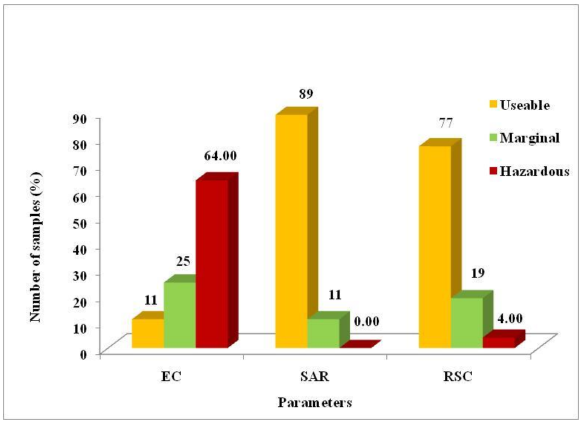

Fig 1. Groundwater quality of taluka Mithi and Islamkot on the basis of EC, SAR and RSC

Table 5. Groundwater quality classes of taluka Mithi and Islamkot

Water Quality Classes	Number of samples	Sampling site numbers
C1S1R1	4	24, 29, 30 and 34
C1S2R1	1	28
C1S2R2	1	14
C2S1R1	11	5, 10, 26, 32, 33, 35, 38, 39, 40, 44 and 48
C2S1R3	1	43
C2S2R2	1	47
C3S1R1	22	1, 2, 3, 4, 6, 8, 9, 11, 12, 13, 15, 16, 17, 20, 21, 22, 37, 41, 42, 49, 50 and 53
C3S1R2	8	7, 18, 25, 36, 45, 46, 51 and 52
C3S1R3	1	23
C3S2R1	3	19 27 and 31

Classification of Groundwater Samples

Groundwater samples were classified (Table 5) in the different groups suggested by WAPDA, 1981, with number of sites including C1S1R1 (4), C1S2R1 (28), C1S2R2 (14), C2S1R1 (11), C2S1R3 (43), C2S2R2 (47), C3S1R1 (22), C3S1R2 (8), C3S1R3 (1), C3S2R1 (3) and C3S2R1 (3). Majority of samples fall in the category C3S1R1 that is saline hazardous, but SAR and RSC in useable limits. Only four samples were of the category C1S1R1 (Good quality water related to all parameters).

Conclusion

Our results reveal that the water bodies samples vary from useable, marginal and hazardous quality as per salinity ECiw and RSC values. However almost all groundwater samples were fall in two categories useable and marginal as of SAR values, whereas no one sample had sodium hazardous for the purpose of irrigation. There were presence of major cations and anions sequence as their abundance in groundwater $Na^{+} > Mg^{2+} > Ca^{2+}$ and $Cl^{-} > HCO_3^{-} > CO_3^{2-}$. The samples were slightly alkaline to highly alkaline pH in nature. All water samples were classified into different groups and each group consists on number of samples like 4, 1, 1, 11, 1, 1, 22, 8, 1 and 3 in separate group C1S1R1, C1S2R1, C1S2R2, C2S1R1, C2S1R3, C2S2R2, C3S1R1, C3S1R2, C3S1R3 and C3S2R1, respectively. In crux, we report that salinity, and not sodicity, was the major threat to the area under irrigation through these water bodies. Hence, we suggest the use of saline-tolearnat crop and their genotypes in these areas for sustainable crop production.

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AN EMPIRICAL STUDY ON WATERBORNE DISEASES FACED BY THE PEOPLE OF JACOBABAD CITY

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ABSTRACT
Waterborne diseases are caused by infected or contaminated water. Every year about 3.4 million people died by water related diseases worldwide. Jacobabad is the underdeveloped city of Sindh province, having population of more than a quarter of million (275,000 est.) and situated at the borders between Sindh and Baluchistan. The city has been deprived from the basic need of safe drinking water and people are using dirty, polluted, adulterated and infected water which is injurious for health. This phenomenon has become a major cause of waterborne diseases which people of Jacobabad are facing day by day. Considering such alarming situation the present study was conducted in civil hospital, Jacobabad from July through September 2016. A written informed consent was taken among 439 patients who visited the hospital during study time. The main six waterborne diseases were observed likewise, Hepatitis A (38%), Typhoid (26%), Diarrhea (16%), Cholera (9%), Dysentery (8%) and Dracunculiasis (3%). From the above collected cases, females were in preponderance with 58.1% and males with 41.9%. The highest ratio of patients belonged to the age group of 21 to 30 years. The majority of the people was using water supplied by Donkey cart vendors which is highly polluted. Waterborne diseases can be controlled if water will be purified and safe for biotic life.

Keywords
Waterborne, Jacobabad, Contaminated, Hepatitis, Drinking water.

Introduction
Water is life but in some regions of the world that same water becomes a tool of death just because of water-related diseases. Typically water-related diseases are categorized in four classes: water-borne (caused by bacteria, viruses and protozoans), water-based (caused by parasitic worms, mosquitoes etc.), water-washed (caused by chemicals, pesticides etc.) and water-related insect vectors (caused by infections). Waterborne diseases are mainly caused by pathogenic microorganisms which are mostly transmitted through the ingestion of contaminated fresh water [1]. The wealthier countries have been eliminated from the burden of waterborne diseases in today's world but the developing countries are still suffering from this hard issue. According to WHO about 1.1 billion people in the world drink impure water [2] while UNISEF reported that approximately 800 million people living in African and Asian countries do not have access to pure and safe drinking water [3]. The most important concern about human life is the quality of water, fecal pollution in drinking water is the central cause of waterborne diseases which can ultimately destroys entire population [4]. In Pakistan, contaminated water by bacteria is the main source of waterborne diseases [5] but the situation of Jacobabad is more dreadful, the increasing population of city is facing problems like bad road infrastructure, poor water storage, squeezed struc-

ture of sanitation and terrible solid waste management [6]. The health facilities in the city are inadequate and people are suffering from so many diseases, especially water-related diseases like Hepatitis, Diarrhea, Malaria, Typhoid, Dysentery, Skin diseases, Eye infections and so on [7]. This paper aims about the prevalence of waterborne diseases in Jacobabad city.

Research Methodology

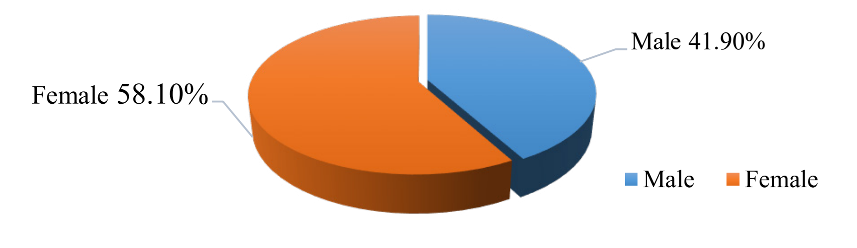
The location of Jacobabad city is 68027'05.04"E and 28016'37.32"N, with an estimated population of 275,000 est. [7]. So the present study was carried out for three months from July to September, 2016 at civil hospital Jacobabad, Sindh, Pakistan. The study was performed after the permission of ethical committee of civil hospital Jacobabad.

Patients were selected on the inclusion and exclusion criteria, so a total of 439 patients were selected for present study because these all were suffering from waterborne diseases and were the residents of Jacobabad city. Written informed pro-forma was also conducted from each patient.

Findings

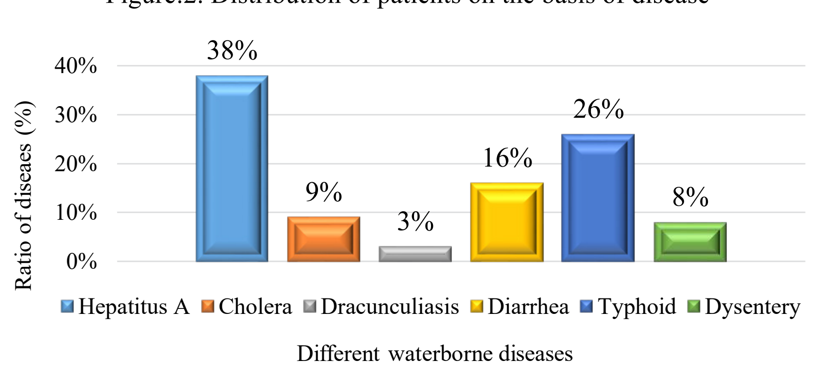
The burden of waterborne diseases is increasing worldwide including Pakistan. Jacobabad city has been deprived from the basic necessities of life especially health facilities, people are suffering from so many diseases [8]. During the study time a total of 1806 patients visited civil hospital, Jacobabad in which 439 patients were diagnosed as waterborne diseases. The females were in preponderance 58.1% and males were 41.9%.

Figure:1. Distribution of patients on the basis of gender



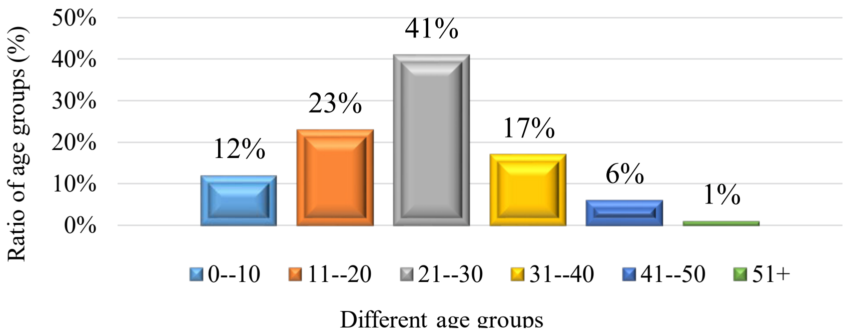
Among 439 patients the six waterborne diseases were diagnosed, the highest in prevalence was Hepatitis A with 38%, followed by Typhoid 26%, Diarrhea 16%, Cholera 9%, Dysentery 8% and Dracunculiasis (Guinea Worm Disease) 3% respectively. The main cause of Hepatitis A is contamination in water by feces while Typhoid is caused by bacteria which can be ingested through infected water or food. An impure water which contains larvae of parasitic worm is the reason of Dracunculiasis (Guinea Worm disease) as far as Diarrhea is concerned it is caused by pathogens which can be found in dirty drinking water by human or animal waste [9].

Figure:2. Distribution of patients on the basis of disease



People of Jacobabad city mainly used water from canals like Jamali Wah and Khirthar, piped water, borehole water, tube well water, Donkey cart vendor's water for drinking and mineral water [7]. So the water is mostly contaminated by bacteria, viruses and protozoans. A number of people are facing these diseases considering all age groups. In present findings people of all ages were suffering from waterborne diseases but the highest ratio was observed in the age group of 21-30 years, second highest ratio was found in 11-20 years of age group.

Figure:3. Distribution of patients on the basis of age groups



According to the written informed consent people belongs to all the Union councils of Jacobabad city, the highest prevalence of diseases were found in residents of UC6 Mochi basti with 24.7% which mentions that water of Mochi basti is so much polluted and adulterated. People also mentioned in pro-forma that they are using water supplied by donkey cart vendors for drinking and cooking.

Table. Distribution of patients by Union councils

Union Councils	Name of UCs	No: of patients	Percentage
UC1	Soomra Mohalla	83	19%
UC2	Lashari Mohalla	16	3.6%
UC3	Shahghazi Mohalla	22	5%
UC4	Family line	46	10.5%
UC5	Phool bagh	50	11.3%
UC6	Mochi basti	108	24.7%
UC7	Jafferabad	54	12.3%
UC8	Dastagir colony	60	13.6%
Total		439	100%

Conclusion

It is concluded on the basis of above findings that drinking water of Jacobabad city is fully contaminated by feces (bacteria, viruses and protozoans) which produces waterborne diseases like Hepatitis A, Guinea Worm disease, Diarrhea, Cholera, Typhoid and Dysentery. Patients suffering from these diseases were belongs to all age groups and the highest ratio was found among the residents of Mochi basti (UC6) while females were in preponderance. Most of the people living in Jacobabad city belongs to lower and lower middle class and they cannot afford mineral or purified water for their drinking so if safe and pure water will be provided to the city, these waterborne diseases can be controlled easily and people can have a healthier life.

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DETECTION OF FUNGI IN INDOOR AIR OF THE IEEM BUILDING, MUET, JAMSHORO

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ABSTRACT

Air within built environment is an important indicator of the health and well-being of people living inside. Indoor air pollution is responsible for various dermal, respiratory and cardiovascular diseases. Respiratory symptoms like coughing and wheezing, rhinitis, asthma, tiredness and headache are mostly associated with fungal presence in indoor environment. Hence, to assess the presence of indoor microbial pollution particularly fungi, experimental study was conducted with in the IEEM Building, Mehran University of Engineering and Technology, Jamshoro. For that purpose, agar plates were prepared for the detection and subsequent enumeration of fungal population within the six selected rooms, two of which were laboratories. Sabouroad Dextrose Agar was used for the selective growth of fungi. Three petri plates each, one of which was used as a control, were placed at 1-meter height in the middle of four classrooms and two laboratories, in the morning and afternoon. Sampling periods for the plates were 30 and 60 minutes. The first reading for fungal population was taken after 24 hours with subsequent incubation and monitoring for 4 days. Control dishes were found free of fungal population, while a significant increase in fungi was measured with time. Further identification of fungi should be carried out by other researchers.

Keywords

Indoor air pollution, fungal detection

Introduction

Indoor air pollution is the introduction of harmful and poisonous substances in the air within and around a building. It started when people began to live in the form of communities, settled at one place, and started to use fire for cooking, light and warmth within buildings (1). The process accelerated with the advent of modern technologies in our daily lives; people began to spend most of their time within buildings and the impacts of indoor air pollution on human health became more obvious.

It is a basic right of everyone to breathe in a healthy indoor environment. The quality of the air within the buildings is an important indicator of the health and well-being of people living in them (2). Various diseases including upper and lower respiratory diseases, reproductive disorders, cardiovascular system malfunctioning, kidney and liver diseases, dermal infections, decreased efficiency of psychological functions are reported to be caused by inadequate air quality (2).

The sources of indoor air pollution might be physical, chemical and biological in nature. Dampness, excess moisture, inadequate ventilation, improper insulation and heating systems enhance the deterioration of indoor air quality. In built environments, some of the commonly found biological contaminants are bacteria, fungi, pollens, viruses, insect body parts, animal dander, and bird droppings (3). Microbial pollutants also include different types of microbes and allergens, which have a capability to spread from person to person. Evidence shows that different types of biological pollutants pose detrimental threats to the indoor air quality. (4)

Dampness and inadequate ventilation are two major reasons for the presence of different types of biological agents within buildings and indoor environments, which result in the deterioration of the quality of indoor air. Excess moisture on different materials within a building leads to higher microbial growth including mould, fungi and bacteria. These microbes pollute the indoor air by producing spores, cells, fragments and volatile organic compounds (VOCs). Another negative impact of dampness is that it causes different materials to degrade chemically and biologically, which also contaminates indoor air. (2)

Contaminated humidifiers or humidification sections of HVAC (Heating, Ventilating and Air Conditioning) installations are often the sources of infectious agents (such as Legionella pn.). Infectious agents may also multiply in other locations which meet their needs in terms of substrate, temperature and humidity. HVAC installations are found to contain and spread biological contaminants relatively frequently, due to poor design, operation and maintenance (5). In homes, sources of biological contaminants are more often formed by damp areas on walls and floors. Several studies have linked "Legionnaires Disease", humidifier fever and bronchopulmonary aspergillosis to agents spread by contaminated HVAC systems or resulting from refurbishing of hospitals (2).

Several infectious diseases are known to be transmitted from one person to the next when infectious agents are propelled into the air by coughing, sneezing, singing, talking, etc. (5). The major reason why airborne infections are much more likely to spread indoors than outdoors is, that the dilution in outdoor air is, usually, so great that the chances of inhaling enough infectious droplet nuclei to become infected are negligible. Also, people spend much more time indoors than outdoors, especially in winter, when respiratory infections are generally more prevalent than in summer.

Fungi enter buildings through deposition on the surfaces of new materials and clothing or through ventilation. Inside the building, growth of fungi depends on moisture. Nutrients like carbohydrates, proteins and lipids are also required for the growth of fungi, which are available inside buildings in the form of plant and animal matter in dust, construction materials, wood, cooking oil and paints and food and paper products. Most fungi grow at temperatures between 10-35ºC, which is mostly maintained within buildings (2). Elevated numbers of fungi and fungal spores in damp buildings shows the dependence of fungal growth on moisture (6) (7).

Direct interaction of fungi with human body may cause physiological disorders, intoxications and infections (8). Exposure to fungi causes adverse health effects, which include respiratory symptoms like coughing and wheezing, rhinitis, asthma, tiredness and headache (9).

This study focuses on the detection and enumeration of indoor air fungi present in the Institute of Environmental Engineering and Management (IEEM), Mehran University of Engineering and Technology (MUET), by settle-plate method. Sabouroad Dextrose Agar (SDA) was used as the media on which fungi was grown. Different sampling times and periods were set to compare fungal growth between them.

Materials and Methods

Preparation of Media

We selected Sabouroad Dextrose Agar (SDA) for the selective growth of fungi. Distilled water was mixed with 4% of SDA. Additionally, Kanamycin 50 µg/ml was added to the agar to prevent bacterial growth. The media was mixed, thoroughly, until no precipitates remained. It was, then autoclaved at 105°C for 15 minutes. The media was cooled down to 55°C and poured in petri plates.

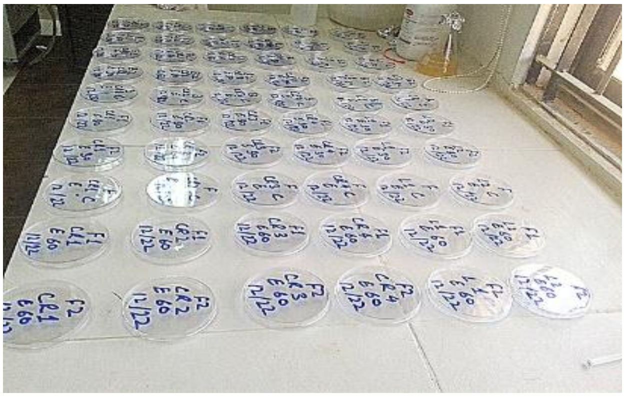

Figure 1 Labelled petri plates before sampling

Sample Collection

To evaluate the concentration of fungi in the indoor air of the IEEM Building, MUET, Jamshoro, passive air sampling was performed. Two open and one closed (control) petri plates were placed in four classrooms and two laboratories. They were placed at 1-meter height, approximately, in the middle of the rooms for periods of 30 and 60 minutes, to evaluate the fungal load with increase in exposure time. Samples were collected in both morning and evening to evaluate the effect of the presence of people on the number of fungal colonies. There were 60 samples altogether. After the collection, samples were incubated at 25°C in the microbiology laboratory of IEEM. The first reading was taken after twenty-four hours with subsequent monitoring for four days.

Figure 2 Morning and evening sampling in the same room

Colony Enumeration

Colony forming units (CFU) were counted by plate-count method. Secondly, CFU/m3 were calculated by using Omeliansky's Formula: N = 5a * 104 (bt)-1 (10).

Where N = microbial CFU/m3 of indoor air; a = number of colonies per Petri plate; b=dish surface (cm2); t=-exposure time (min).

The average of two samples was taken for the number of colonies per petri plate.

Results

The indoor air fungal loads of four classrooms and two laboratories of IEEM were detected using 60 samples. The first reading was taken after 24 hours, keeping the objective of daily inspection in consideration. On the first day, highest CFU/m3 were detected in the Microbiology Laboratory (30-minute exposure time) in the evening. However, there was no growth in Classroom 4 (30-minute exposure time) both in the morning and evening. Classrooms 2 and 3 also showed high number of colonies at 60-minute exposure in the morning.

Table 1: First day reads: number of CFU/m3 at two different exposure times in morning and evening.

Sampling Time	**Petri Plate Exposure Time (Minutes)**	**Sampling Sites**					
		Class room 1	Classroo m 2	Classroo m 3	Classroo m 4	Microbiology Laboratory	GIS Laboratory
Morning	30	26	52	13	0	26	13
	60	33	105	105	20	52	20
Evening	30	52	13	52	0	183	26
	60	20	7	52	20	46	20

As percentage of detected fungi increases with passing days (11), daily inspection was the initial plan but, after two days, when petri plates were inspected, large overlapping colonies had been formed, which had become uncountable. Large colonies had engulfed smaller colonies.

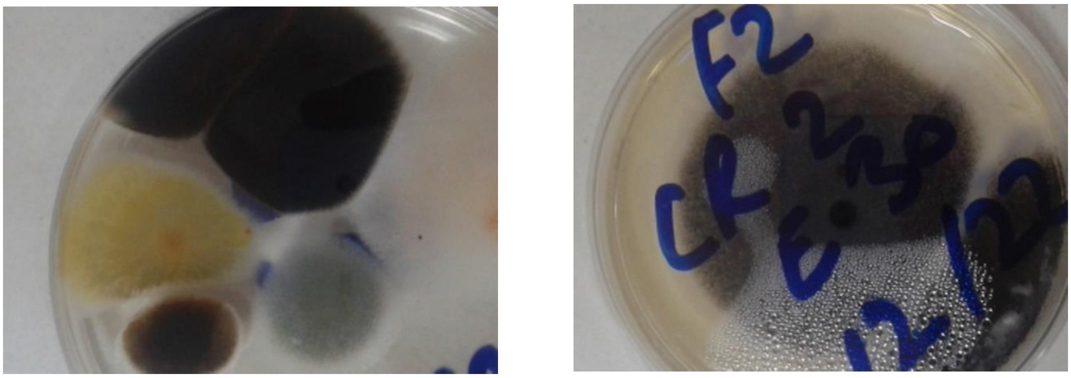

Figure 3 Growth of fungal colonies on petri plates

Discussion

Initially, it was planned to incubate fungi for 7 days. However, colonies after the two days became uncountable in all samples. This showed that the quality of air was largely unhealthy, even for healthy persons. Due to the presence of heavy fungal load, occupants of the building are at the risk of several diseases including rhinitis, asthma, conjunctivitis, coughing and wheezing, and allergy. Furthermore, pathogenic fungi do not need to be in higher quantity to affect the health of the occupants. This is an alarming situation and poses a considerable risk to the health of students, teachers and laboratory technicians alike.

The true characterization and quantification of fungi present in the air was limited because of the use of a culture-based method. Standard methods have not been developed, till date, to enumerate fungi in indoor environments, which further limits the quantification and understanding of the impacts of fungal presence in indoor air.

Because all colonies had become uncountable, detailed statistical analyses, which would have established the relationship of fungal presence with samples collected during different times of day as well as the exposure time, couldn't be carried out.

To conclude, every room examined, contained high number of fungi. Therefore, there is a need to give special attention to control indoor environmental factors that promote the growth of fungi. Improved ventilation should be supplied in classrooms, laboratories, kitchens and restrooms. Relative humidity should be maintained to minimize dampness and moisture in the air. Lastly, any leaks in water pipes should be repaired. Detailed studies should be carried out to identify and quantify fungi to assess the risk occupants of the building are exposed to.

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COMPARISON OF INOCULUM TYPE ON THE BIO-GAS POTENTIAL OF WHEAT STRAW AT LOWER AND HIGHER ORGANIC LOADING RATE

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ABSTRACT

Inoculum plays a vital role in providing initial microbial population in anaerobic process. There is unavailability of standard inoculum in the region and available inoculums require pretreatment (dewatering, sieving, and pre-incubation), uncontrolled feeding may lead process failure in short period. Thus, in this study, the effect of inoculum type (digested manure and acclimatized sludge) at lower (2gVS/L) and higher (10gVS/L) organic loading rate on the biogas production of wheat straw was evaluated. For this purpose, Biochemical Methane Potential (BMP) assays were conducted in 300 ml serum bottles, all the bottles were filled with the known amount of substrate and inoculum at 1:1 on volatile solid basis. Bottles were sealed with rubber stopper and aluminum cap, headspace flush with nitrogen gas to ensure anaerobic condition, and placed in an incubator under mesophilic condition. Digested manure and acclimatized sludge were collected, sieved through 2mm sieve for the removal of bigger organic particles and incubated under mesophilic and anaerobic conditions for 14 days before being used as inoculum. Higher biogas yield of 599 ml/gVS was observed from wheat straw with digested manure as compared to other inoculum was 397 ml/gVS at 2gVS/L. Highest volatile solid removal 70 % was observed from the wheat straw inoculated with digested manure at organic loading rate 2gVS/L. Reactor inoculated with digested manure showed better buffering capacity in terms of pH, as final pH was 7.1 as compared to acclimatized sludge. Reactors inoculated with digested manure have optimum carbon to nitrogen ratio as compared to acclimatized sludge. Further, result of the study will be useful to manage agricultural by-products (wheat straw) judiciously.

Keywords

Biochemical Methane Potential, Digested manure, Inoculum, Sludge, Organic loading rate, Wheat straw

Introduction

Pakistan is an energy deficient country and facing numerous problem due to the growing energy demands [1]. To overcome energy crisis country is looking towards different renewable energy options [2]. In promoting renewable alternative, bioenergy can play a key role, as, bioenergy is predicted as the fourth largest energy resource in the world [3].

Biomass fuel has received considerable attention in recent years because of increasing concerns over energy depletion and the environmental pollution caused by fossil fuels [4]. Anaerobic digestion of these agricultural by-products can be considered as one of the promising technique to convert organic waste into renewable bioenergy [5].

There are enormous sources of biomass available for the generation of bioenergy in Pakistan [6]. It produces around 69 million tons of agricultural field based crop residues per year [7]. The average annual production of wheat in Pakistan is 25,214 million tons from which wheat straw production is 37820 million tons [8].

The waste agricultural straw, cannot be digested by itself. Thus, in digesting agricultural straws (wheat straw) anaerobic microorganisms are required for starting the anaerobic digestion process. An active inoculum is required in providing initial microbial population. Digestates or sludge from anaerobic engineering project for waste water treatment have been the prominent sources for these inoculums [9]. However, due to the presence of very few anaerobic wastewater treatment plants, standard anaerobic inoculums are not available in Pakistan. Mostly, sludge and manures based inoculums, which are also considered as standard inoculum are thus used in conducting anaerobic digestion research at lab scale. Because, these two sources are readily available in the country.

Lignocellulosic structure of the waste agricultural straws (wheat straw) are the main hindrance in their microbial degradation [10]. Thus, the good inoculum source can affect the digestion process. An active inoculum can enhance biogas yield, solid removal and make anaerobic digestion more stable [11]. Furthermore, a suitable inoculum source can provide extra nitrogen and nutrient source [12]. As sufficient nutrient and trace elements are found in manure [13]. Micronutrients quantity in an inoculum can effectively enhance the biogas production [14]. Waste agricultural straws has low nitrogen content, which leads to a decrease in biogas [15]. Inoculum such as sludge and manure being rich in nitrogen content, can provide additional nitrogen to enhance the activity of methanogens.

Inoculum characteristics, mostly depends on pre-treatment procedure and storage conditions [16]. Inoculation and organic loading rate are very important parameters for the optimization of the anaerobic digestion process. Selection of inoculum source and the quantity of inoculum plays effective role in the assessment of biodegradability of substrates [17]. Different type of biomass give different biogas production, that can be assessed using the Biochemical Methane Potential (BMP) assays. The BMP is an effective tool to assess the biodegradability and biogas yield of biomass [18]. Therefore, it is important to compare lower and higher loading rate of a biomass using available inoculums for biogas production, volatile solids removal, nutrient content and buffer capacity.

The overall objective of this study is to compare the effect of two different inoculums at higher and lower loading rate on biogas production, buffer capacity and nutrition content. Further, this study can be helpful in providing detailed information on two main types of inoculum, because there was no standard inoculum available in the region.

Materials and Method

Substrates and Inoculum

Wheat straw was used as substrate in the study. Wheat straw was collected from local farmer near study area. Substrate was collected, crushed with lab scale crusher for size reduction up to 5 mm, sieved through 5mm sieve to get the uniform size, stored at 4 OC until used.

Two different inoculum (Digested manure and acclimatized sludge) were used in the study. Digested manure was collected from local biogas plant digesting manure near Islamabad and sludge was collected from pilot scale 100 L capacity anaerobic digester treating MBR sludge. Inoculums were prepared, according to the method describe by [19].

Experimental Setup

Biochemical methane potential experiment was conducted on the principle described by [20] with some modifications. In this study 300 ml serum bottles were used with working volume of 225 ml. Known quantities of substrate and inoculum as shown in Table 1 on volatile solids basis were added in the serum bottles. Bottles were sealed with rubber septum and aluminum crimp cap. Anaerobic condition in the reactors were ensured by flushing pure Nitrogen gas. Reactor bottles were placed in an incubator for 45 days under mesophilic temperature (37 OC). Mixing was provided manually twice a day, mixing once or more in a day for Biochemical Methane Potential is sufficient [21]. No external nutrient was provided, all the nutrients were provided by fresh inoculums (Digested manure and acclimatized sludge) [22]

Experimental Condition

In this study, two different inoculums (Digested manure and sludge) were compared for their effect on biogas production at lower (2gVS/L) and higher (10gVS/L) organic loading rate. Quantities of substrate and inoculum added to achieve substrate to inoculum (S/I) ratio of 1 (on gVS basis) are shown in Table 1. To get the biogas production from inoculum, control reactor of inoculums was also prepared. In this study four combinations of reactors were prepared, R1 (inoculated with acclimatized sludge at lower loading rate), R2 (inoculated with digested manure at lower loading rate), R3 (inoculated with acclimatized sludge at higher loading rate), R4 (inoculated with digested manure at higher loading rate). The experiment was carried out at mesophilic temperature (37 oC).

Table 1. Quantity of Substrate and Inoculum at S/I 1

Parameter	Wheat Straw	Digested Manure	Acclimatized Sludge
pH	5.9	6.9	7.5
TS (% TS)	90	6.89	4.99
VS (% TS)	94.4	70.75	70.14
TOC (% TS)	54.75	41	40.68
TKN (% TS)	1.11	4.2	3.2
C/N	49.77	9.7	12.7

Analytical Parameters

For feedstock characterization, fresh samples of substrate and both the inoculum were analyzed for total solids (TS), volatile solids (VS), pH, volatile fatty acid (VFA) and alkalinity. Total kjeldehl nitrogen (TKN) and total organic carbon (TOC) of substrates and inoculum were also determined.

Daily biogas production was measured with glass syringe. Total organic carbon was calculated with help of equation 1 [23]. Total kjeldehl nitrogen (TKN), volatile fatty acids (VFAs), total solids (TS), volatile Solids (VS), pH and alkalinity of digester samples were determined as per recommended standard methods [24].

$$OC=VS\ (\%\ of\ TS)/1.724 \rightarrow (1)$$

Volatile solids removal % were calculated with the help of equation 2

$$VS\ removal\ (\%)=((VS\ (added)-VS(Final))/VS(added))*100 \rightarrow (2)$$

Results and Discussion

Feedstock Characteristics

Feedstock characteristics are very important parameters in operating and designing of anaerobic digester. These initial characteristics of feedstock strongly affect startup, process stability and biogas production during anaerobic digestion. Initial pH of wheat straw was 5.9, while initial pH of digested manure and acclimatized sludge was 6.9 and 7.5 respectively. Wheat straw has very high volatile solid content i.e., 94.4 % TS. Table 2 shows the initial feedstock characteristics. Wheat straw has low nitrogen and high carbon content, whereas C/N ratio of both the inoculums are low in the range of 10 – 13.

Table 1. Quantity of Substrate and Inoculum at S/I 1

Substrate	Quantity Added	g VS Added	OLR (gVS/L)
Wheat Straw	0.54g	0.45	2
Wheat Straw	2.65g	2.25	10
Digested Manure	9.3 ml	0.45	2
Digested Manure	46.5 ml	2.25	10
Acclimatized Sludge	12.92 ml	0.45	2
Acclimatized Sludge	64.5 ml	2.25	10

Effect of inoculum type on the biogas production

In this study two main type of inoculums digested manure and sludge were compared at lower and higher loading rate. The biogas yields from the anaerobic digestion of wheat straw inoculated with digested manure and sludge at lower and higher loading rate is presented in Fig 1. Digested manure and acclimatized sludge give higher biogas yield at lower organic loading rate as compared to higher organic loading rate during starting days of digestion. Digested manure at higher organic loading rate gave noticeable biogas yield trend after 8 days of digestion. Highest normal daily biogas yield of 36.7 Nml/gVS was observed after 22 days of digestion from wheat straw inoculated with digested manure at organic loading rate of 2gVS/L as shown in Fig 1a. Lowest biogas yield was observed from the reactor inoculated with acclimatized sludge at organic loading rate of 10gVS/L. Reactors inoculated with digested manure were more efficient than acclimatized sludge.

Cumulative biogas yields from reactors R1, R2, R3 and R4 were 397, 599, 365 and 532 Nml/gVS respectively. Highest cumulative biogas yield of 599 Nml/gVS was observed from the reactor inoculated with digested manure at lower organic loading rate as shown in Fig1b. Lowest cumulative biogas yield was noticed from the reactor inoculated with acclimatized sludge at higher loading rate as shown in Fig 1b. Without pH adjustment or external alkalinity addition, pretreatment, sludge contained higher easily degradable carbon than the digested manures in higher quantity, which might have caused acidification and lower biogas production during anaerobic digestion. Based on the mentioned results in Fig 1, it can be clearly concluded that differences existed between digested manure and acclimatized sludge, when used as an inoculum. Higher and steadier biogas yield was observed from the reactors inoculated with digested manure. Both the inoculums performed well at organic loading rate of 2 gVS/L as compared to higher loading rate of 10 gVS/L.

Fig. 1a. Daily biogas yield from different reactors

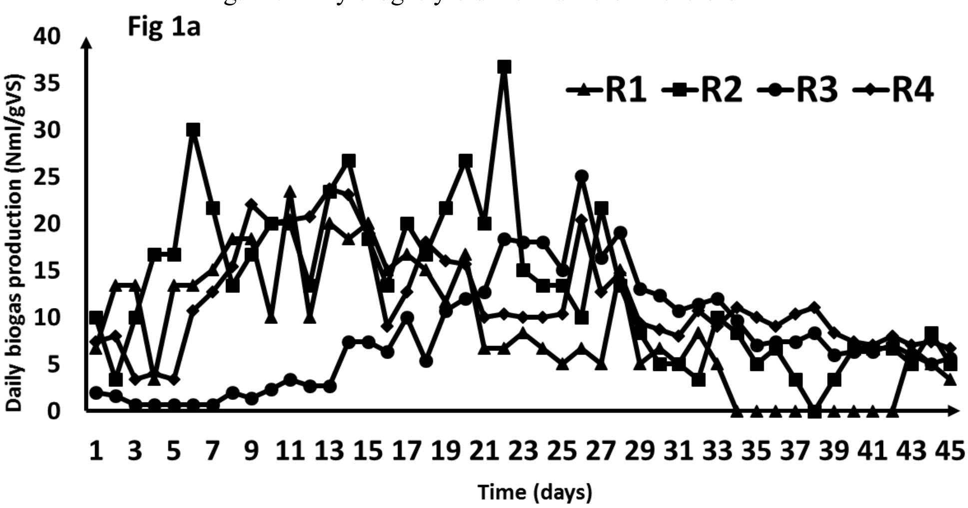
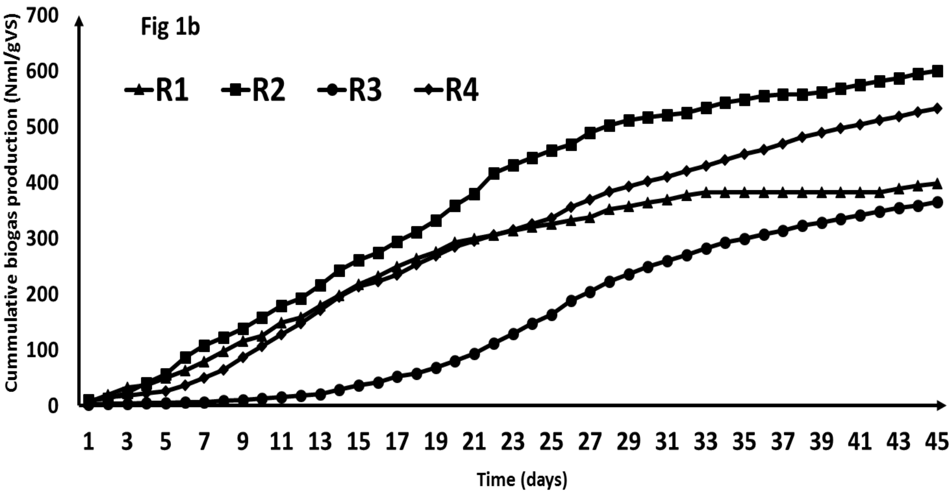


Fig. 1b. Cumulative biogas Yield from different reactors

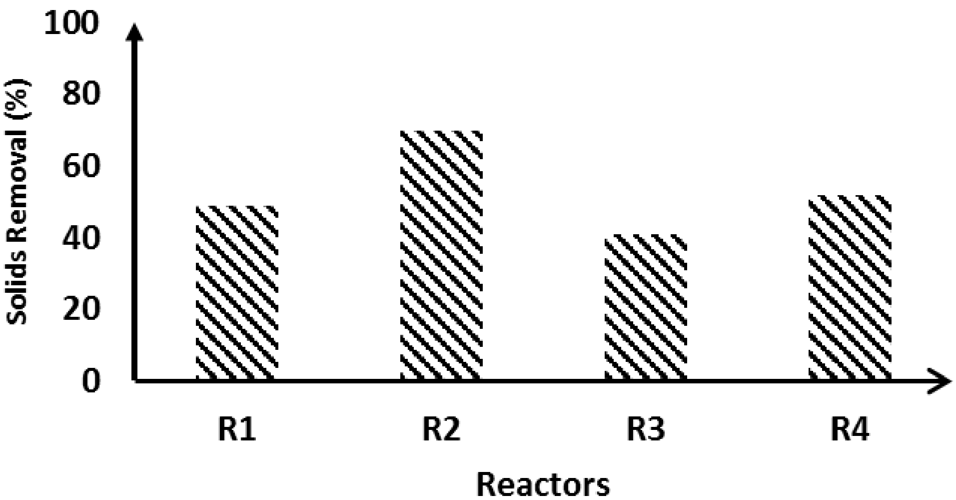


Results of the study are similar to another study [25] which compared different inoculum sources for the anaerobic digestion of rice straw, in which digested manure performed better in terms of higher biogas yield, buffer capacity and nutrient content. Biogas yield in the present study is higher than another study [26]. Higher biogas yield can be due to inoculum preparation or lower organic loading rate, because, higher organic loading rate can increase VFAs accumulation.

Effect of inoculum type on solids removal

Volatile solids (VS) reduction from four reactors is shown in Fig 2. Highest VS reduction of 70% was observed from reactor R2, while lowest VS reduction of 42% was observed from reactors R3. Higher volatile solids (VS) reduction yielded higher production of biogas as trend in volatile solids (VS) removal was same as biogas yield. Highest solids removal was observed from wheat straw inoculated with digested manure and acclimatized sludge at lower loading rate. Higher organic loading rate yielded lower solids reduction. There is a strong relation between solids removal and biogas yield. Another study found a similar relationship of higher biogas production and solids removal from the anaerobic digestion of rice straw [27].

Fig. 2. Volatile Solids removal from various reactors



Effect of Inoculum type on buffer capacity and reactors stability

Initial and final pH of all the reactors were measured as presented in Fig 3. Methane producing bacteria requires optimal pH range of 6.5-8.2 [28], when pH value is higher than 8.5 it has toxic effects on the anaerobic digestion [15]. Initial values of pH in all the reactors ranged between 7.4-7.8, all the values were in suitable range for anaerobic digestion. Final pH of all the reactors were in a healthy range as shown in Fig 3.

Alkalinity is another reliable parameter after pH to assess the imbalance of digester. In this study, only source of alkalinity were inoculums. No extra alkalinity was provided in this experiment. Initial and final alkalinity of digester are shown in Fig 4. Reactor inoculated with digested manure showed higher initial and final alkalinity. Due to higher initial and final alkalinity biogas yield were higher in digesters inoculated with digested manure at both lower and higher organic loading rate.

Initial and final Volatile fatty acids (VFAs) concentration in all the reactors inoculated with digested manure and acclimatized sludge at both the organic loading rate were within optimum range as shown in Fig 5. VFAs concentration higher than 5000 mg/L may inhibit anaerobic digestion [29].

Another important parameter in monitoring of digester stability is VFA/Alkalinity ratio. All the reactors inoculated with both the inoculums at lower and higher organic loading rate showed desirable range except R3, which was slightly higher than recommended range as shown in fig 6. According to a study [30], VFAs/TA ratio should be less the 0.4. It can be concluded that digester inoculated with digested manure at both the loading rate were showing better buffering capacity based on VFA/TA ratio.

Fig. 3. Initial and final pH of reactors

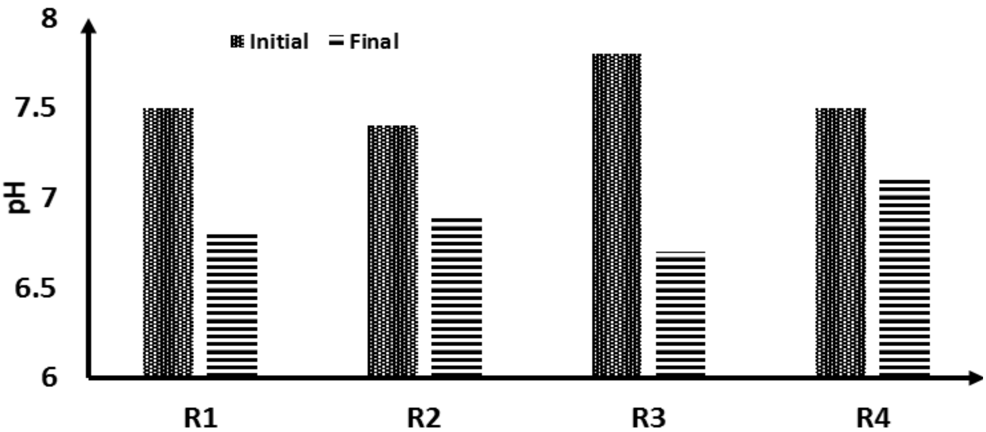


Fig. 4. Initial and final alkalinity of reactors

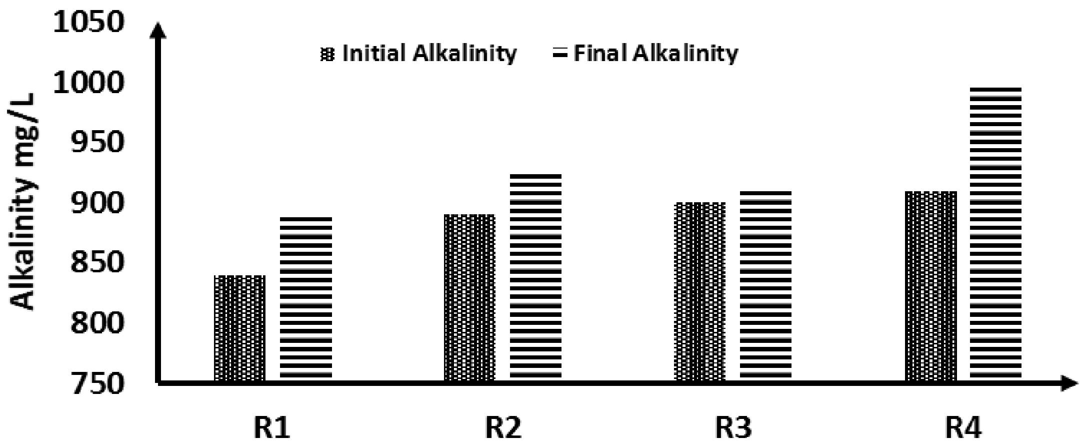


Fig. 5. Initial and final VFAs of reactors

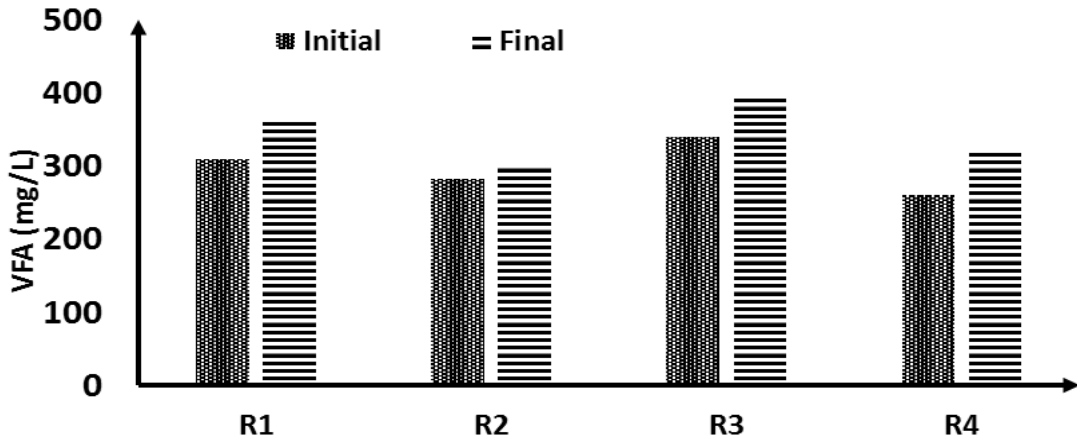
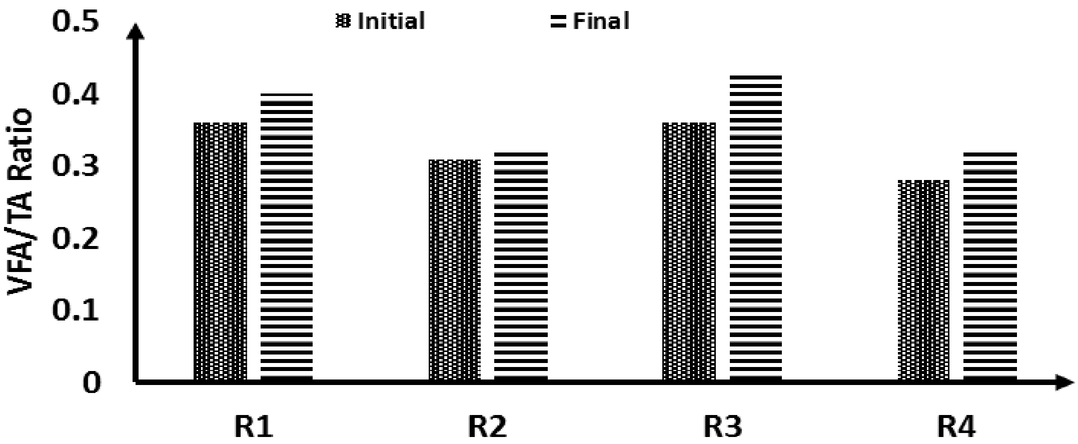


Fig. 6. Initial and final VFA/TA ratio of reactors



Carbon to Nitrogen Content

In this study, after inoculation of reactors carbon to nitrogen ratio was calculated and shown in Table 3. Many studies suggested that carbon to nitrogen ratio for anaerobic digestion should be in optimum range 20 – 30 [15]. Reactors inoculated with digested manure has a Carbon to Nitrogen C/N ratio 29.5. Because of optimum carbon to nitrogen ratio biogas production was higher in the reactors inoculated with digested manure at both the organic loading rate. Reactors inoculated with acclimatized sludge has slightly higher carbon to nitrogen ratio this can be one such reason of lower biogas production.

Table 3. Carbon to nitrogen contents of reactors

Reactors	Digested manure	Acclimatized sludge
C/N	29.51	30.91

Conclusion

Significant difference in performance of reactors inoculated with different inoculums were noticed at both the organic loading rate in terms of biogas yield, buffer capacity and volatile solids removal. Digested manure and acclimatized sludge performed better at lower organic loading rate. Reactors inoculated with digested manure and acclimatized sludge at lower organic loading rate have shorter start-up time. Digested manure inoculated reactors performed better in comparison with acclimatized sludge at both the organic loading rate. Lower biogas yield was observed from the reactors inoculated with acclimatized sludge at higher loading rate. Digested manure showed higher biogas yield, better buffering capacity, higher volatile solids removal and carbon to nitrogen balance at 2 gVS/L as compared to acclimatized sludge.

Acknowledgments

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TREATMENT OF DOMESTIC WASTEWATER BY SUSTAINABLE MICROBIAL FUEL CELLS HAVING AN INEXPENSIVE, RELIABLE AND RECYCLABLE ANODES

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ABSTRACT

Treatment of wastewater by using Microbial Fuel Cells (MFCs) have been proven as a promising but challenging technology so far. Researchers are coming up with different techniques every time to overcome the bottle necks in this technology. One of the current issues is fouling of the electrodes which is hindering its commercialization. Depositions on electrodes reduce the working efficiency of the cell. In such cases, material selection of electrodes plays a significant role. The electrodes must be low-priced, non-corrodible, reliable and reusable. This research deals with the designing and fabrication of a single chamber MFC with an inexpensive, recyclable material (acrylonitrile butadiene styrene substrate, ABS) used as an anode to treat the domestic wastewater. Activated carbon air-cathode was used where a biofilm was developed. The Current and voltage across the cell were measured by a Multi-meter. The efficiency of the fabricated single chamber MFC was checked by measuring the instantaneous Chemical Oxygen Demand (COD) and power generation with the utilization of organics in the wastewater. A current density of 67.5 mA/m2 and power density of 1.6 mW/m2 was generated in a single chamber microbial fuel cell having a hydraulic retention time of 48 hours. The COD reduction varied from 51% to 60% which proved the existence of exoelectrogens in the domestic wastewater. These bacteria can be identified and used as inoculum in future studies to obtain high COD removal rate treating the same domestic wastewater. The experiment also showed the successful application of carbon nanotube-based conductive paint polymer support as anode in treating the domestic wastewater. However, the performance decreased gradually due to the deposition of inorganics on the cathode which can be studied further in future. Moreover, the design of this new anode could be studied in future to maximize the surface area for microbial colonization to obtain more power output.

Keywords

Microbial Fuel Cells, Anode material, Carbon nanotubes conductive paint, Polymer support, Air Cathodes, exoelectrogens.

Introduction

According to data released by the World Resources Institute (2013), Pakistan is predicted to be one of the most water stressed country by 2040. The energy and water sources are increasingly getting limited due to rapid growth of population. Additionally, copious amounts of wastewater and environmental deterioration further exacerbate the problem. With such a critical situation, Pakistan lacks behind in treating its wastewater. According to Pak-SCEA (2006), approximately only 8% of the wastewater produced in Pakistan is treated by the very few existing treatment plants. Furthermore, it is also observed that this figure decreases i.e. only 1% of the wastewater produced is actually treated in the country (PWSS, 2002) due to the fact that the existing treatment plants have aged and many are out of commission and/or not in proper working order to efficiently treat wastewater. As a result of this infrastructure shortfall, domestic wastewater, including household effluent and human waste in Pakistan, is directly discharged into sewer system, a natural drain or a water body, a nearby field or an internal non-engineered septic tank, which is even more harmful to human health and the natural environment because wastewater leeches into the water table. Similarly, the industrial, agricultural and municipal wastewater is discharged into water bodies directly or without fulfilling the country's discharge standards. Treating these diverse types of wastewater can contribute at its best to solve the water crises. Pakistan, being a developing country is lacking behind in treating its wastewater because the treatment methods so far popularly adopted are adequate for treating wastewater of various compositions but, at present, are very costly. A huge amount of energy is required to produce, collect, transport, treat and then discharge the treated water (Pham, 2006). Pakistan has spent an estimated US$ 9 billion importing energy between 2008-2009 in order to fulfill current energy demands (Rehman et al., 2013). The energy intensive and costly conventional treatment methods are making wastewater treatment unaffordable for developing countries. The scientific community is struggling to maximize desired outputs from renewable sources. Solar, wind, bioenergy and other forms of renewable energy have begun contributing to the Earth's environmental protection. Recently, microbial fuel cells (MFCs) have been getting tremendous attention in the scientific world. MFCs are a biotechnology that uses bacteria to extract energy stored in the chemical bonds using microbial activities under anaerobic conditions. Thus far, anaerobic digestion has proven to extract energy from wastewater (Li, 2014). Research on MFCs began in the early twentieth century (Lewis, 1966); it was known at that time that electricity can be generated from waste using bacteria and those bacteria capable of performing electron exchange mechanism are called exoelectrogens (Kumar, et al., 2015). Since then, MFCs have been studied extensively as the biotechnology, and the requirement for economical waste reuse innovation, has progressed.

The most promising application of MFCs is their use in wastewater treatment technology (Minghua Zhou, et al., 2012). Moreover, McCarty (2011) evaluated the benefits of domestic wastewater treatment anaerobically compared to activated sludge system and he found that anaerobic treatment produces methane two times higher than conventional aerobic treatment with a large amount of energy production more than the plant operation demand. So, anaerobic treatment of domestic wastewater could be used as a net energy producer. Domestic wastewater treatment has been tested in MFCs by many researcher (Logan, 2010, zielke, 2005 & Liu et al., 2004). Maximum COD reduction of range 60% to 80% have been previously reported by using domestic wastewater depending upon different Hydraulic Retention Time (HRT) and MFC designs (Kim et al., 2016), but has reported serious issues of electrode fouling like other MFC researchers (Zhang et al., 2014). Currently, the researchers are working to explore sustainable electrodes to achieve stable and desired results (Grattieri et al., 2017). The aim of this study is to establish a sustainable MFC at laboratory to treat domestic wastewater sustainably. CNT-based plastic polymer anodes were used as sustainable anodes in a Single Chamber Microbial Fuel Cell (SCMFC) which were not used previously for treatment of wastewater. This study aims to check the successful application of these cheaper and reliable anodes to treat wastewater in a SCMFC which can reduce the excessive cost of anodes. Moreover, while using any substrate, we must explore or know that there are any bacteria (exoelectrogens) present in the substrate to act as a catalyst and participate in electron transfer activity because not all bacteria have the capability to exchange the electrons with the electrodes without any mediator. Another aim of this study is to explore the presence of mediator-less exoelectrorgens in the domestic wastewater by relating the COD reduction and power generation directly. To achieve this objective, no other bacterial culture was inoculated in the wastewater. The existing bacteria were tested to colonize the electrodes and perform the electron transfer activity.

Materials and Methods

All MFCs have same operating principle but due to different substrates and output options, they have different modifications in their shapes.

In this research, the SCMFC consisted of a L-Shape single chamber made of Pyrex glass with the base length of 8cm and the vertical length of 13 cm was used. The diameter was 5 cm and the total empty volume of the SCMFC was 200 mL. The SCMFC was having an opening at both ends (Top and at the end of L shape) where the electrodes were placed.

ANODE

Acrylonitrile butadiene styrene substrate (ABS) was used as the support for anode coated with 4 to 5 percent carbon nanotubes conductive paint (Verniciature Bresciane s.r.l., Castegnato, Italy). The paint makes the ABS support conductive with which bacteria exchanged their electrons by colonizing on it. The thickness of paint coating and electric resistivity were 30 µm and 22 Ω per square respectively. The price of the anodes depends upon the thickness of the coating and the carbon nano-tubes content. The cost ranges from 1000 to 5000 PKR per square meters. The electrical connections were made by following the process used by Grattieri et al. (2017). The anodes have 2 cm x 5.5cm dimensions. The dimensions were selected according to the dimensions of the chambers in which the electrodes must be fully dipped. The anode used in this study is shown is figure 1a.

CATHODE

The air porous cathode was made of a thin layer of Activated carbon (AC) and Carbon nano tubes (CNT) powder mixture in Polyethylene terephthalate (PET) Polymer, bonded to a stainless-steel mesh. Activated carbon and carbon nano tube were mixed at a ratio of 10:1. 35% of weight of PET of the AC/CNT was mixed with PET and kept on stirring for about two hours. After two hours, the solution was poured onto the stainless-steel mesh and kept on drying for at least 8 hours. A hard layer was formed bonded with the mesh was used as cathode in the SCMFCs. Figure 1b shows the prepared cathode which has been used in this study.

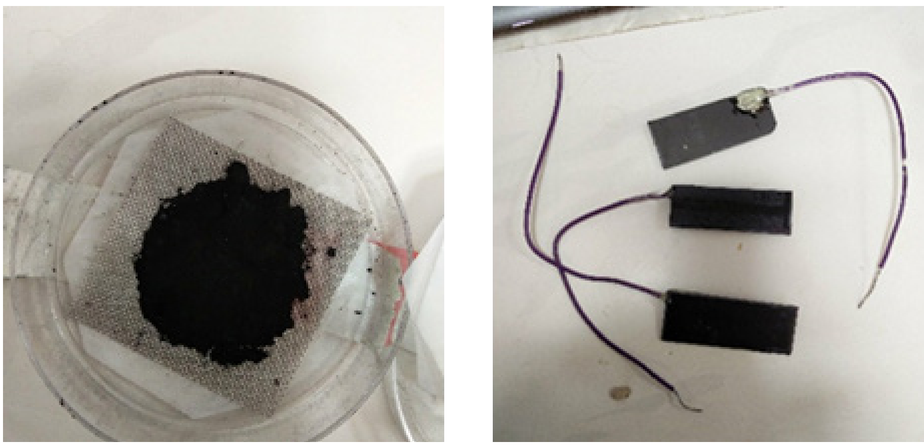

Figure 2. (a) CNT based polymer support anodes. (b) AC/CNT based air diffusion cathodes

MFC Setup

The L-shaped MFC with working volume of 175 mL was set up in the Institute of Environmental Engineering and Management (IEEM), Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan Wastewater Laboratory. The prepared electrodes were placed at both openings. Copper wire was used to make the circuit connections consisting a 310 Ω resistor. A multimeter was connected parallel to resistor to record the voltage generated. All the connections were checked to make sure of good connectivity. Local domestic wastewater was collected from the septic tank of IEEM, Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan. Wastewater was fed into the reactor without making any changes to the properties. The pH of the wastewater ranged from 7.12 to 7.50 and a COD of 1280 mg/L was recorded initially. The experiment was held at room temperature of 30 OC to 35 OC. The wastewater filled MFC was sealed to provide anaerobic conditions and operated for four days in batch mode. The schematic and pictorial view of the SCMFC is shown is figure 2.

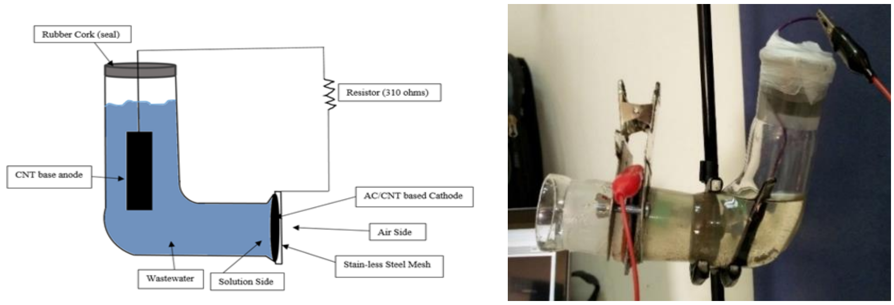

Figure 2. (a) Schematic diagram (b) Laboratory scale prototype of SCMFC for wastewater treatment.

Analysis

The voltage and current was measured with the multimeter connected across the circuit. The current was also checked by the formula; I = V/R, where I is the current, V is the voltage and R is the external resistance. The power density 'P' will be calculated as P = V2/R*A, where A is the surface area of cathode (Yuan, et al., 2011). COD was measured according to standard methods and the pH was measured with a standard pH meter. A relationship between COD removal and Power generation was developed.

Results and Discussions

Electricity was produced in the MFC by using domestic wastewater with initial COD of 1280 mg/L is shown in figure 3. The voltage across the load of 310 Ω increased up to 23 mV, producing a current density of 67.5 mA/m2 and a maximum power density of 1.6 mW/m2 based on the surface area of the anode in 48 hours.

Potential Difference Trends

The potential difference across the load of resistance 310 Ω is shown in the figure 4. The potential difference started to develop two days after the MFC started up. The domestic wastewater was not inoculated with specific bacterial culture but the existing bacteria in the wastewater needed two days to develop the potential difference. The third day, a maximum value of 23 mV was recorded. The potential difference started decreasing after this maximum value which was then followed by the addition of fresh wastewater at 5th day. The potential started increasing again but not to the previous peak value. The peak value recorded after this addition was 17 mV which started decreasing to 6.2 mV at the 6th day. The same pattern of decrease in potential was observed in our previous work with Great Salt Lake water as substrate using the same anodes where it was explored that the anodes were stable and good to work but the decrease in performance was due to the instability of cathode with the passage of time (Grattieri et al., 2017). The cathodes performance is decreased due to the deposition of inorganics hindering the electron transfer activity.

Chemical Oxygen Demand

The COD reduction was observed is shown in Figure 5. It ranged from 51% to 60%. With the influent COD of 1280 mg/L the COD removed to 60% in 48 hours. At this point, after the significant drop of voltage to 6.2 mV, new fresh wastewater was added to the SCMFC with COD of 1124 mg/L. After another 48 hours, the COD reduced to 51% decreasing the power as well.

COD and Power relationship

A positive relationship is found between the power generation and the COD reduction showing that the bacteria present in the domestic wastewater sample are capable of participating in the electron exchange activity. This relationship is show in figure 6a. The power kept on decreasing after 48th hour. This can be linked with the COD that with lesser amount of food remaining, lower is the electron generation process. The power density as a function of HRT is shown in figure 6b.

Conclusion

A single-chamber MFC was successfully established at laboratory scale. The domestic wastewater having a COD of 1280 mg/L was degraded up to 60% in initial time of 48 hours, generating a maximum voltage of 23 mV and a current density of 67.5 mA/m2. The positive relationship between COD reduction and power generation showed that there are exoelectrogens present in the wastewater sample which participated in the electron transfer mechanism, breaking the organic matter and successfully transporting the electrons to anode. In the second cycle, when wastewater containing 1124 mg/L of COD was fed, the removal decreased to 51%. The less breakdown of organics eventually resulted in lower power generation showing that the exoelectrogens participation has decreased. As a result, the electron flux decreased. So, it was explored that the exoelectrogens were there to perform the breakdown of organics and exchange electrons with the anode resulting in power generation. These species can be identified and used as inoculum for the treatment of wastewater much efficiently.

The anodes used in this study are cheap, reliable, recyclable and durable. These anodes were not used to treat wastewater previously. This study showed that the CNT- based anodes could be successfully used to treat wastewater with comparable.

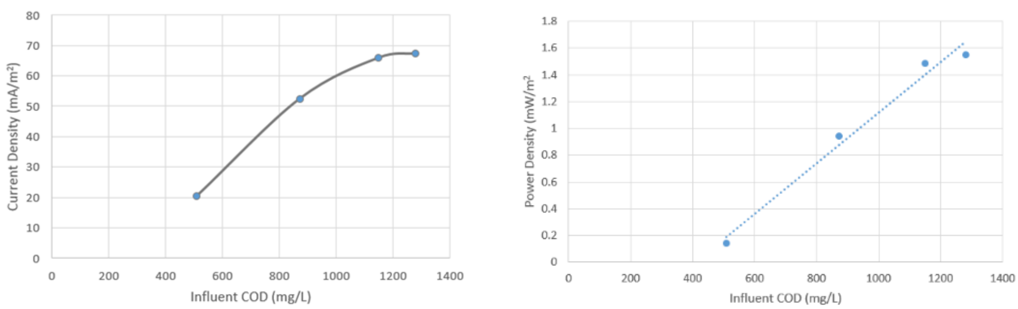

Figure 3. Current density as a function of influent wastewater COD for HRT = 24 hours

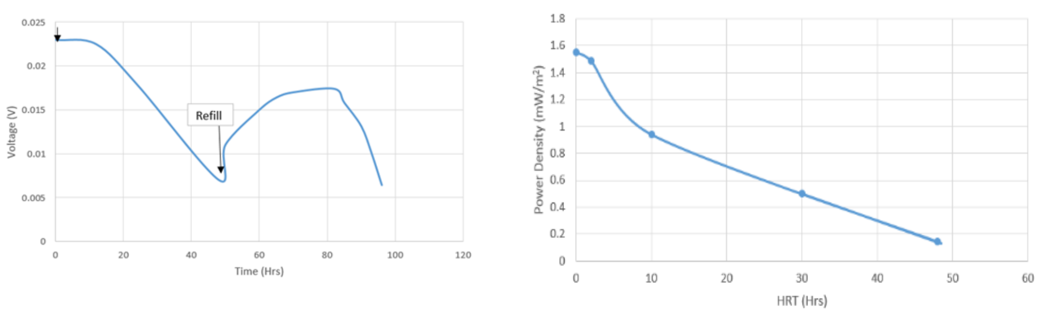

Figure 4. The potential difference across a 310 Ω resistor as a function of time. The arrow mark shows the point at which the wastewater sample was refilled (cycle II).

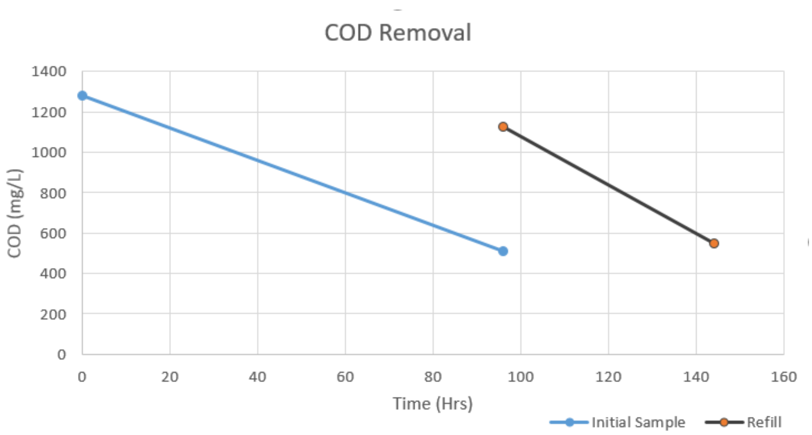

Figure 3. The COD reduction rate in the SCMFC. The refill graph shows the COD reduction for second cycle after refilling with fresh wastewater.

performance to other anodes (carbon brushes, carbon cloth, graphite anodes, cupper etc.) used so far which are expensive and not stable over a certain period of time. Although, the performance is similar to these expensive cathodes but with much greater physical stability and lower cost.

Figure 4. (a) Power generation as a function of influent COD in the domestic wastewater sample for first 48 hours after the potential has been established. (b) Power density as a function of HRT (COD = 1280 mg/L, 310 Ω).

producing a small amount of current density and voltage with the reduction of COD. In order to increase the power density of the MFC, it is needed to identify the exoelectrogens by characterization and use the culture to inoculate the particular domestic wastewater. These active bacteria can speed up the COD reduction process by vigorous degradation and as a result a stable current density can be achieved.

However, the CNT-based plastic polymer anodes are stable, durable and recyclable but it is recommended to work on the anode to maximize the surface area for the bacteria where they can colonize and communicate with the anode better than previously reported. Furthermore, the anode's efficiency is directly linked with the cathode (Grattieri et al., 2017) therefore, it is needed to improve the cathode material as well. Replacement of cathodes with the passage of time could be minimized by exploring some recyclable and reliable material for cathodes as well.

Acknowledgment

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Recommendations

This study has explored the possibility of treating the domestic wastewater in typical Pakistani conditions. Also, it showed the presence of exoeletrogens in the domestic wastewater by

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Melanoidins Removal from Bio-digested Spent Wash using fly ash

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ABSTRACT

One aim of this study was to utilize the fly ash generated from coal fired power plant to produce a cost effective and sustainable technique to replace conventional cost intensive methods for melanoidins color removal from biodigested distillery wastewater. In this study, a real melanoidins content wastewater was collected from local molasses based distillery and preserved at 4oC before use. A fly ash sample was collected from coal Jamshoro power plant, sieved to collect a smallest particle size fly ash (0.15mm). The fly adsorbent was prepared by acid treatment after several washing through distilled water and drying at 105oC overnight. Batch Experiment was performed in conical flask as a function of contact time, adsorbent dose, pH and initial dilution of wastewater to optimize suitable conditions. Equilibrium adsorption data was interpreted through Langmuir and frendulich isotherms models, while kinetic data was analyzed through pseudo-first-order and pseud-second-order- kinetic models. Langmuir isotherm and pseudo-second-order kinetic model were found to best fitted to equilibrium and kinetic data with R2 value of 0.9639 and 0.9998 respectively. After 2 hours of contact time, 91 % of melanoidins removal efficiency was achieved at optimum adsorbent dose of 5 gm. The optimum dilution of spent wash was 5%, while pH and temperature were 7 and 303k respectively.

Keywords

Melanoidins, Fly Ash, Spent wash, ADMI

Introduction

Molasses, a byproduct generated in the sugar production industry, is used as a common raw material in the fermentation industries such as ethanol production and baker's yeast because of its low cost and high sugar content. However, a large quantity of wastewater generated in fermentation process of molasses to ethanol known as spent wash with high organic content and dark brown in color.

Convectional biological treatment process such as activated sludge and anaerobic digestion are capable to reduce biochemical oxygen demand from spent wash due to presence of the high organic contents. However, a dark brown color remains or some time intensified in the biologically treated spent wash due to re-polymerization of the pigments. Dark brown color in the spent wash is due to the presence of the high molecular weight compound, known as melanoidins, are formed at last stage of the Millard reaction, a non-enzymatic reaction between amino acids and carbohydrates [1]. Melanoidins are resistant to biodegradation due to its anti-oxidant nature, when released in the fresh water, reduces the sunlight penetration and also reduce Dissolved oxygen and photosynthesis activity [2].

Different approaches have been investigated to remove color causing Melanoidins from the biodigested distillery effluent, such as Fenton's oxidation [4], Adsorption on activated carbon [5], electrochemical oxidation using different electrolytes [6], Nano filtration and reverse osmosis [7]. Besides these physicochemical treatments, biological treatment through different microorganism such as white rot fungi have also been investigated and found that they are capable of degrading melanoidins in certain nutrient conditions. These methods, however have certain limitation because they are less capable to remove color, high operating and equipment cost and generate large quantity of potentially hazardous byproducts [8]. Up till now, no any method have been successfully applied for the biodigested spent wash treatment. Therefore, there is urgent need to have a cost-effective techniques to minimize the pollution load of the distillery wastewater.

Coagulation/flocculation is one of the widely used method to remove color causing compound along with certain organic and particulate matter in the wastewater treatment. The Conventional coagulants used in the wastewater treatment are ferric chloride ($FeCl3-6H2O$), Sodium aluminate and alum ($Al2 (SO4)3-14H2O$) [9]. However, according to some studies, aluminum silicate present in the effluent creates environmental problem, also some time alum reacts with natural alkalinity present in the water leading to reduction of pH [10].

Currently, it is proved that adsorption on activated carbon is most effective and widely used technique to remove color causing compound from the industrial wastewater[], along with certain particulate matters but due to high cost of the activated carbon, it is some time ignored and not adopted. However, this technique will become inexpensive if expensive activated carbon is replaced by low cost adsorbent material with no any additional pretreatment. In coal fired thermal power plant, fly ash is generated as a byproduct in huge quantity. Globally, about 700 million tons of coal fly ash is generated annually, only significant quantities of which is utilized for the specific purpose like substitute for cement in a concrete, still huge amount is discarded as a solid waste, which ultimately creating environmental problem such as air pollution and require disposal[11]. The coal fly ash can be used as a good adsorbent for the removal of color causing dyes from industrial effluent [12]. The adsorbent capacity of the fly ash for the reactive dye removal were studied by different researchers, such as adsorption of the C.I black (129 mg/g), remazol blue (18 mg/g), remazol red (128 mg/g) [13-14]. It is found from the previous studies that fly ash has a good adsorption potential to remove color causing compound and can be used for the removal of color causing Melanoidins from the distillery wastewater.

Aim of this study is to utilize a solid waste generated in the form of fly ash in coal fired thermal power plant in order to produce a low cost techniques for distillery wastewater treatment and reduce pollution load from both power plant and distillery. In this study, Batch experiment was performed to optimize suitable conditions such as effect of pH, Initial dilution and adsorbent dose. Experimental data were interpreted through Langmuir and Frendulich isotherms, kinetic study were performed through two adsorption kinetic model, Pseudo first order and Pseudo second order kinetic models.

Experimental

Materials & Methods

Distillery wastewater

In this study, a real melanoidins content wastewater was collected from molasses based ethanol production distillery, located in District Matiari near Hyderabad, Sindh, Pakistan. Overall industry is divided into three section, Fermentation section, Distillation section and Biogas plant as shown in Figure 1. Molasses from sugar industry is used as a feed stock in fermentation section where it is fermented into mixture of ethanol and spent wash known as fermented mash. Ethanol from fermented mash is then separated from mixture in Distillation unit and then condensed and stored in the storage tank, spent wash is stored in the storage pit and used as feed stock in the Bio gas plant. They have four anaerobic digesters where spent wash is anaerobically digested to produce methane gas, biodigested spent wash after passing through four aerobic lagoons is discarded.

Biodigested distillery effluent sample for this study was collected in amber glass reagent bottles from discharges line of the lagoon and preserved at 4oC before use [14]. Physico-chemical parameters were analyzed before treatment as shown in table 1.

Table 1. Physicochemical Properties biodigested distillery effluent

Parameters	Units	Values
COD	mg/l	9000-10,000
BOD	mg/l	2500-2800
Color	abs/cm	2.20
pH	----	6.5-7.5
Temperature	ºC	20
TSS	mg/l	5300
TDS	mg/l	12600
Chloride	mg/l	3.33
Ammonia	mg/l	557

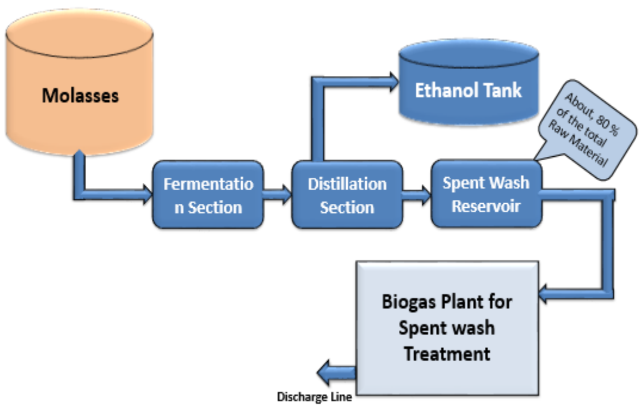

Table 1. Physicochemical Properties biodigested distillery effluent

Coal Fly Ash:

Fly ash sample was collected from coal fired thermal power plant located in district jamshoro, Sindh, Pakistan. They use coal as a fuel to produce energy, while burning of coal, fly ash is generated as a solid waste in huge quantity. Samples of fly ash for this study was collected from electrostatic precipitator installed near stack.

Chemical composition of the coal fly ash, shown in table.2, indicates that it has potential to adsorbed pollutants from wastewater [15]. Therefore, in this study it was decided to utilize solid waste (fly ash) to treat distillery wastewater in order to produce cost effective and sustainable treatment technique which will reduces the pollution load from both the industries in compliance to NEQs standard.

Collected sample of fly ash was sieved through sieve set to collect different particle size of the fly ash. Smallest particle size will have larger surface area and have good adsorption capacity. Fly ash having particle size of 0.15 mm particle was used in this study to optimize suitable conditions. The sieved fly ash were washed several time with Distilled water followed by acid treatment to remove other dust particle and dried at 105oC overnight in oven before use as an adsorbent.

Table 1. Physicochemical Properties biodigested distillery effluent

Elements	Percentage (%)
Lithium oxide (Lio)	14.58
Silica Oxide (SiO2)	23.61
Aluminum tri-oxide (Al_2O_3)	14.09
Ferric oxide (Fe_2O_3)	9.15
Calcium oxide (CaO)	22.89
Magnesium oxide (MgO)	2.71
Silica tri-oxide (SO_3)	13.13

Melanoidins analysis:

Melanoidins is a high molecular weight color causing compound present in the distillery wastewater followed the ADMI (American Dye Manufacture institute) color index, which was developed to monitor wastewater quality. This method, relies on the measurement of transmittance in 31 wavelengths from 40 to 700 nm, with 10 nm steps [16]. Double beam UV visible spectrophotometer was used to measure the color of wastewater before and after treatment.

After completion of the adsorption process, solution was centrifuged and filtered through Whatman 42 filter paper, filtrate was taken for the measurement of the color. Distilled water was provided as a blank to check the extent of absorbance. Amount of melanoidins adsorbed q (mg/g) was calculated using eq.1

$$q = \frac{(Co - Ce)}{m} \times V$$

Where, Co: Melanoidins initial concentration in solution (g/l); Ce: concentration of the melanoidins after treatment (g/l); m: mass of adsorbent (mg): and V: Volume of the solution. Percent removal of melanoidins was calculated using equation 2.

$$\%R = \frac{(Co - Ce)}{Co} \times 100$$

Batch Studies:

To find out suitable conditions at which maximum removal of melanoidins could be achieved, a batch study was performed at different adsorbent dose, pH, and initial concentration. In Each experiment, equally weighed fly ash was added to 50 ml biodigested wastewater in 100 ml conical flask and mixture was agitated at 120 rpm in incubated shaker at constant temperature. At the same time two controls were provided one with mercuric sulfate to avoid bacterial interaction and second without mercuric sulfate to avoid interaction of light. After competition of adsorption, Solution was filtered through Whatman 42 filter paper and analyzed in UV Visible double beam spectrophotometer. Amount of melanoidins adsorbed and % removal was calculated using equation 1 and 2 respectively.

Results and Discussion:

Effect of different conditions on adsorption

Effect of contact time on percent melanoidins removal is shown in figure 2. Maximum color removal was achieved at initial stage of adsorption process as shown in graph, there was sudden increased in percent removal during initial 30 minutes of adsorption process, after that there was only significant increase in color removal. Effect of adsorbent dose on the percent melanoidins removal, shown in Figure 3. The removal efficiency increases with increased amount of adsorbent dose from 1 gm to 6 gm. Maximum 91 % removal efficiency was achieved at 5 gm adsorbent dose, further increased of adsorbent was not have significant effect further effect.

However, it was decreased with increased amount of adsorbent because fly ash particle interacts with equilibrium concentration of the melanoidins. pH of the solution is another important parameter which effects on adsorption process, it is shown in figure 3, pH 2-6 is favorable for maximum color removal.

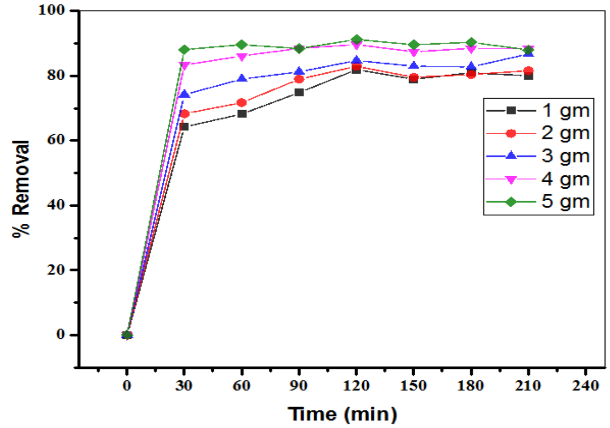

Figure 2. Effect of Contact time on Percent Melanoidins removal (Temperature 303 k, Dilution 5 %, pH-7)

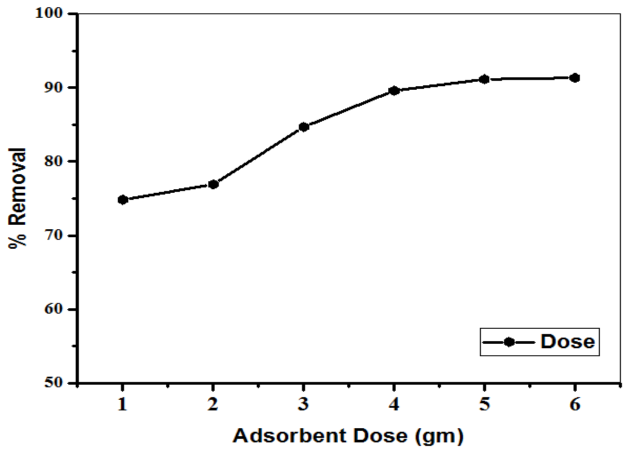

Figure 3. Effect of Adsorbent Dose on percent Melanoidins Removal
(Temperature 303k, Dilution 5%, pH-7, Dose 5 gm).

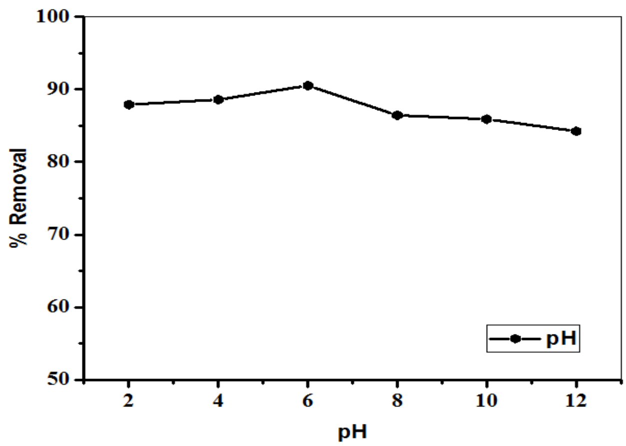

Figure 4. Effect of pH on Percent Melanoidins Removal (Temperature 303k, Dilution 5%, Dose 5gm)

Adsorption Isotherms:

To design industrial adsorption column, prediction of batch adsorption isotherm is necessary. Overall adsorption process depends upon the physical and chemicals properties of adsorbent and also on the system conditions. Two adsorption isotherms, Langmuir and Frendulich were selected to analyze batch Experimental results.

Langmuir isotherm model was developed to predict monolayer adsorption of pollutant on the active sites of adsorbent material. It is represented as follows

$$qe = \frac{(q_m K_L C_e)}{(1 + K_L C_e)}$$

Linearized form (3)

$$\frac{1}{q_e} = \frac{1}{k_l q_m C_e} + \frac{1}{q_m}$$

Graph between Ce and Ce/qe will give straight line.

Frendulich adsorption isotherm was most widely used empirical isotherm model which was developed to predict exponential distribution and surface heterogeneity of the active site adsorbent material to words adsorbent [17]. Mathematically it is represented as follows.

$$q_e = k_f C^{1/n}$$

Linearized form (5)

$$lnq_e = lnk_f + \frac{1}{n} lnC_e$$

Batch experimental results were analyzed nonlinearly through Langmuir and frendulich isotherms as shown in figure 5 and 6, correlation coefficient of both isotherms are shown in table 5. It was found that adsorption best follow the Langmuir isotherm than frendulich.

Batch Experimental data were fitted into Langmuir and Frendulich adsorption isotherm models as shown in figure 5 and 6, r square values are shown in table 3. R2 value of both Langmuir and Frendulich isotherms were lies between 0 and 1, which indicates that both isotherms are favorable. However, R2 value of Langmuir is greater than Frendulich means that Langmuir is best fitted then frendulich.

Table 5. Langmuir and frendulich isotherms parameters obtained by linear fitting for adsorbent

Isotherms	**Parameters**		
Langmuir	q_m	K_L	R^2
	36.27	0.0025	0.90628
Frendulich	n	K_f	R^2
	2.61	1.78	0.885

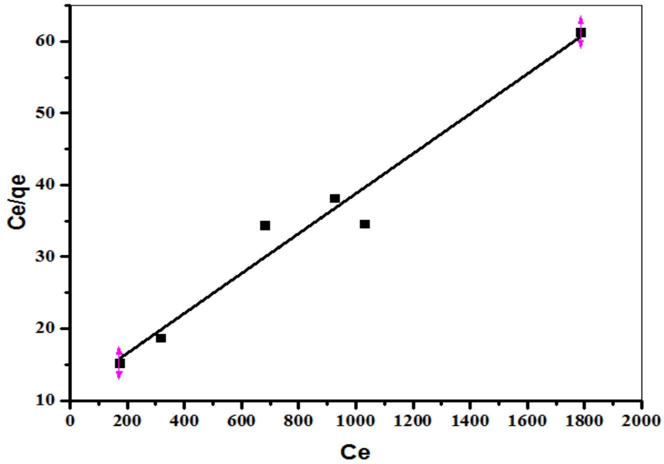

Figure 5. Langmuir Isotherm model

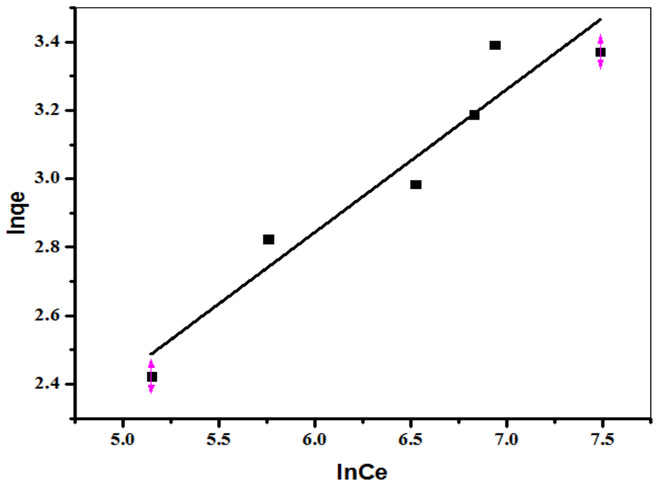

Figure 5. Langmuir Isotherm model

Adsorption Kinetics:

To understand the mechanism of the adsorption of melanoidins on fly ash, pseudo first and second order kinetic models were used to analyze the kinetic data. These models are based on the different assumptions, first order kinetic model is based on the assumption that adsorption rate is related to the unoccupied adsorptive sites and only one adsorbate can adsorb onto one adsorptive site on the adsorbent surface [18]. It is represented as follows

$$\frac{dq_t}{dt} = k_1(q_e - q_t)$$

Integrating both side we get (7)

$$\ln(q_e - q_t) = lnq_e - \frac{K_1 t}{2.303}$$

Graph between ln (qe - qt) and t will give straight line (8)

Pseudo first order kinetic model is based on the assumption that adsorption rate is related to the squared product of the difference between the number of equilibrium adsorptive site on to adsorbent and that of the occupied sites. It is represented as follows

$$\frac{dq_t}{dt} = K_2(q_e - q_t)^2$$

Integration both side qt = 0 and qt= qe and t=0 to t=t, gives (9)

$$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e}$$

Graph between t/qt and t will give straight line (10)

Adsorption kinetic data were analyzed linearly through pseudo first and second order kinetic model as shown in figure 6 and 7, correlation coefficient of both the models are shown in table 6. According to R2 value, it was found that adsorption process best followed the pseudo second order then first order kinetic.

Table 6. Pseudo first and second order kinetic model parameters

Kinetic models	Parameters		
Pseudo first order	q_e	K_1	R^2
	2.3626	0.0202	0.9113
Pseudo second order	q_e	K_2	R^2
	13.477	0.0976	0.9998

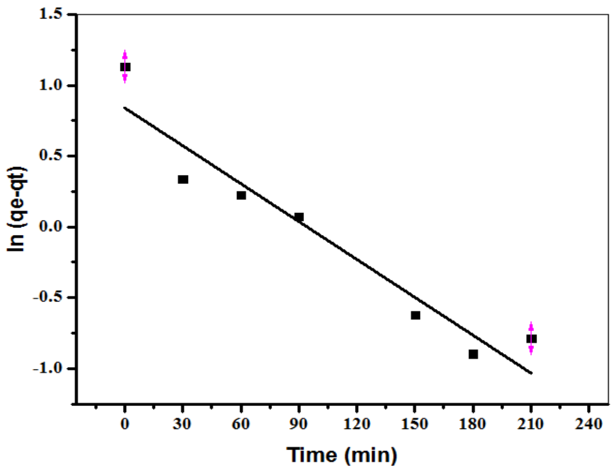

Figure 7. Pseudo first order kinetic plot

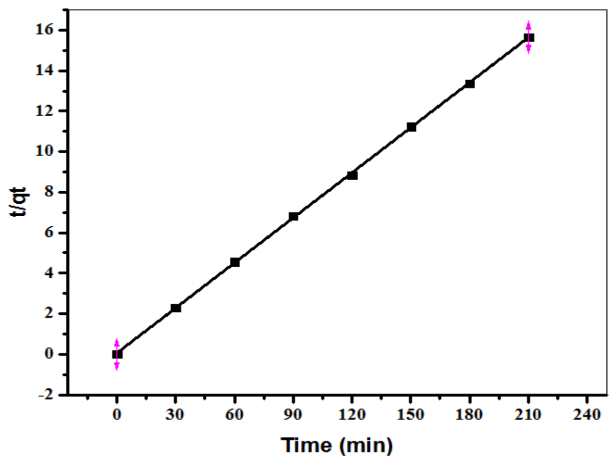

Figure 8. Pseudo second order kinetic plot

Conclusion

Following are conclusion of the study.

1. In this study, a solid waste (fly ash) generated form a thermal power plant has an excellent potential to adsorb pollutants from distillery wastewater. This batch study can further be extended to develop a large scale adsorption column to remove the Melanoidins color which is a requirement of Sindh EPA for sugar industry.
2. Equilibrium adsorption data was interpreted through Langmuir and frendulich isotherms models which best fitted to the equilibrium data with R2 value of 0.9639.
3. The kinetic data was also analyzed through pseudo first and second order kinetic model and was found that pseudo second order kinetic model was best fitted to the kinetic data, with R2 value of 0.998
4. Experimental data proved that fly ash had a good adsorption capacity, maximum 91 % of melanoidins removal efficiency was achieved at 5 gm dose of fly ash in contact time of 120 minutes. The optimum dilution of spent wash was 5%, while pH and temperature were 7 and 303k respectively.

Acknowledgement

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EVALUATION OF OXY-FUEL TECHNOLOGY FOR NOX REDUCTION, CARBON CAPTURE AND SEQUESTRATION FOR THAR COAL

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ABSTRACT

Greenhouse gasses are one of the major concerns throughout the world due to their prominent role in global climate change. The Carbon Capture & Sequestration (CCS) is a promising solution to control anthropogenic carbon emission from power plants. CO2 emissions from power plants can be converted into useful products. Oxy-fuel technology is a promising technology to reduce NOX, with additional unit of CCS. In Oxy-fuel combustion, increased percentage of oxygen is provided to completely burn the fuel. The CCS cost decreases due to decrease in amount of flue gasses and increased concentration of the CO2. Consequently, the size of flue gas treatment system is reduced. It limits the NOX formation and eliminate the need of its treatment, making the cost of NOX treatment equipment and air separation unit (ASU) comparable. In this study, the numeric-simulation based analysis is done to get the theoretical emphases and analyze the benefit of using oxy-fuel in combustion for coal. The decrease in the size of flue gas treatment system is observed along with the flue gas condensation for carbon capture and sequestration. Thar coal is used as a fuel to theoretically calculate the flue gas volume and composition and the size of the flue gas treatment equipment. The process is simulated using ASPEN HYSYS software. Result shows due to presence of N2 in the flue gas, heat losses are up to 69% and in the absence of N2, treatment equipment of the flue gas is reduced to 1/3rd. The comparison between the air-combustion and Oxy-fuel-combustion technology indicates the benefits of using Oxy-fuel to reduce the anthropogenic carbon emission from coal fired power plants.

Keywords

Carbon capture and sequestration, NOx reduction, Oxy-fuel, power plant and Thar coal.

Introduction

Oxy-fuel is a prominent technology to change the environment in which flue gas burned. The oxygen rich air provides high flame temperature. The purpose of oxyfuel is to facilitate the CCS (Carbon capture and sequestration) process. Oxy fuel combustion is in the process of finding ways to be economic. In case of coal, the power required for the process of separating oxygen and nitrogen is 15% of the coal plant [1]. There are several papers which claims the oxyfuel as an economical technology. It would save the fuel needed and the NOx generated [2]. Combining both two purpose of oxyfuel the cost saving in terms of NOx reduction and Carbon dioxide capture process might give the economic advantage. It might be possible to make a baseline in terms of oxygen cost and saving in terms of reducing heat loss and equipment reduction. In case of incineration and where the excess air requirement is high to achieve full combustion, the oxy-fuel acts as an edge by cutting excess air requirement.

It is an evident fact that the world is not converting to renewable sources very soon. There is still time for fossil fuel rejection. In near future, fossil fuels will be the prominent source of fuel and carbon dioxide will be the main pollutant. To cope with the need of emission standards, carbon capture technologies are unavoidable. Currently focused research areas in this subject are oxyfuel combustion, pre-combustion capture and post combustion capture.

In using Oxy-fuel technology, the major impendent is the operating cost of the Air Separation Unit (ASU) unit. For sustainability of oxy-fuel process, it is necessary to make it efficient and comparable to CO2 return value. NOx, VOC and unburned carbon in emission can be effectively reduced in oxyfuel combustion system. It can achieve near zero emissions target [1]. It is a promising technology which can reduces the furnace volume requirement as well as flue gas treatment cost by 1/3rd. Improved burning reduces the requirement of fuel; heat loss can be avoided in terms of excess heat carried away by excessive volume of N2gas in emissions.

The objective of this study is to determine the impact in terms of reducing the size of equipment of flue gas in post combustion process and to get the idea of the impacts of using oxy-fuel in water condensation. The purpose of study is to find the economic way to reduce the potential environmental impacts of Thar coal power plant for the oxy-fuel process.

Oxyfuel Technology

Mostly the oxy-fuel is used where the temperature requirement in the furnace is high. In the glass manufacturing furnaces, the temperature requirement is above 1500˚C. This temperature can easily be achieved using oxy-fuel while it is difficult to control the process using normal air. The oxy-fuel is successfully implemented in the reverb metal furnaces and rotary furnace.

In the furnaces and boilers where full load production is required, it seems to be effective and economically proved. It reduces the cost per unit of metal produced. It is important to remember, oxy-fuel can create a drastic effect by not contacting the surface in half load or low operation [4].

Commonly, two practices are done while using oxyfuel. One is the FGR (flue gas recirculation) and another is air-oxy fuel. Air-oxy-fuel contributes in controlling the atmosphere inside the furnace. In air-oxy fuel, enhance percentage of oxygen is supplied in the furnace controlling the atmosphere. It give economic benefit of reducing the fuel requirement to heat same amount of material or same amount of water due to less heat loss in terms of flue gas heat loss in form of N2. The benefit of the oxy-fuel, air-oxy fuel or CO2-oxy fuel, high temperature in the furnace can be utilized in two places. When high temperature is needed in furnace to maintain load and where the high Calorific Value fuel is not available to sustain normal temperature and supplementary fuel having high calorific value is supplied to contain combustion. Example of low calorific value fuel furnace is the case of municipal waste incineration [5].

Co^2 Capture

There are three basic routes of carbon capture; pre-combustion capture, post combustion capture, and oxy fuel combustion capture. In these three processes, it is apparent that the overall net efficiency of power plant, the cost of CO2 avoided, and the cost of electricity are comparable in all the routes. Sorption, membrane, and cryogenic processes are mainly used for industrial separation and purification of CO2.

The flue gas can be condensed by two methods; direct contact and indirect contact. Direct contact condensing has the advantage of the non-exposure of any heat transfer surface to the corrosion while Indirect flue gas condensation has the advantage of the net power generation in terms of Organic Rankine Cycle (ORC) [7].

Methodology

The data of ultimate analysis of Thar coal has taken from the paper [8]. The data analyze by the calculations of material balance, energy balance and the designing of the flue gas treatment system using the methods of the book "Environmental Engineering" [9]. The numeric-simulation based analysis is done to get the theoretical insights and benefits of using oxy-fuel in combustion of coal. Stoichiometric spreadsheet calculations have been done to analyze the situation and further the simulation is done on Hysys for the better understanding of the process. The entire process is based on imaginary 50 MW power plant. The assumed efficiency and coal consumption is 75% and 12000 kg/hr respectively.

Results and Discussion

The oxy-fuel shows the benefit of saving coal, considering the case in which oxygen is not produce on-site. The usage of Coal for the 50 MW power production is 12000 kg/hr. with conventional burning and 11440 kg/hr. with oxy-fuel. Saving of 560 kg/hr. of coal is evaluated which itself is a source of pollutant when burned. It generates particulate and gaseous pollutants. Volume of flue gas decreases from 142,040 m3/hr. to 36,520 m3/hr. Heat loss reduces from the 16000 to 4900 MJ /kg. N2 heat loss from stack in conventional burning is 69%.

Table 2. Mass balance of conventional vs. oxy-fuel combustion

	Conventional		**Oxyfuel**	
Coal	**12000**	**Kg/hr**	**11443**	**kg/hr**
Fuel	wt. %	weight	wt. %	Weight
Moisture	15.92	1911	15.92	1822
C	51.2	6144	51.2	5859
H	4.97	597	4.97	569
N	0.31	37	0.31	36
O	14.9	1788	14.9	1705
S	2.45	294	2.45	280
Ash/non-combustible	10.24	1229	10.24	1172
Total	100	12000	100	11443

Table 3. Emission mass balance calculations

	Conventional		**Oxyfuel**	
Flue Gas	**weight**	**Vol, m3**	**weight**	**Vol, m3**
CO2	22528	17781	21482	16955
H2O	7293	14070	6944	13396
SO2	588	319	561	304
N2	84970	105388	1290	15867
O2	4110	4461	3920	4254
Ash/particulates	24	21	23	20
Total	119513	142039	34208	36516

Air Composition		**Oxy fuel Composition**	
N_2	76.86	N_2	4.987
O_2	23.12	O_2	95
Water vapor	0.0132	Water vapor	0.0132
Total	100	Total	100

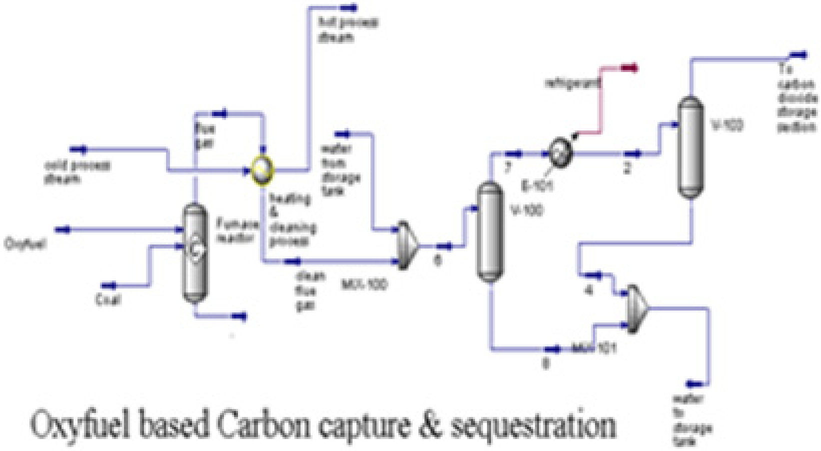

Figure 1. Process simulation using Hysys

Since to maintain the flame temperature and inside atmosphere of furnace, the percentage of N2 is displaced by FGR. This would control the flame temperature and make process fit to retrofit with existing furnace size and decrease in FGR. The thermal NOx generation can reduce up to 80% due to FGR. Thar coal based power plant might use oxy-fuel technology for cleaner and efficient production. NaOH use to remove SO2 in flue gas treatment. 34.12 kg of NaOH is saved per hour with oxy-fuel configuration.

Table 4: Results

	Conventional fuel	Oxy-fuel burning	
Coal Use, Kg/hr	12000	11440	560 kg/hr. , 4.5 %
Volume of flue gas, m3	14200	36500	74% Reduction
Heat Loss , MJ/kg	16000	4900	70% Reduction
Cyclone efficiency	45%	73%	28% Improvement
Electrostatic precipitator, plate area	910	230	74 % Reduction
SO2 Scrubber Cross sectional area, m2	13.2	3.4	74% Reduction
NaOH , Kg	735	700	35 , 4.5 % Reduction

Conclusion

It is noted that oxy-fuel appears to be the most suitable method where the flue gas temperature requirement is high like in case of revert, hearth furnace in metallurgical sites. In glass industry temperature require in furnace is above 1500ºC which is hardly achieved in the air burning environment. The heat loss in terms of nitrogen gas heating is saved by using the oxy fuel process. It reduces the fuel amount and the pollutants associated with the burning of the fuel. Due to reduction in the amount of flue gas, the flue gas treatment equipment size reduces. The operating cost also decreases due to the improved efficiency. The need of NOx treatment unit in the coal power plant is eliminated because oxy-fuel reduce the 75-85% of the NOx formation in the combustion. The cost of the production/purchase of oxygen may well be comparable with the capital and operating cost of the NOx treatment equipment. The carbon dioxide can be captured by the cryogenic process followed by the membrane treatment process. The carbon capture cost reduces due the increased concentration of carbon dioxide in the flue gas. The benefit of selling of the carbon dioxide is the margin of profit. Hence, the oxy-fuel can be useful and a viable option for carbon capture and NOx reduction.

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STRATEGIC ENVIRONMENTAL ASSESSMENT OF PARTICIPATORY IRRIGATION MANAGEMENT IN SINDH PROVINCE

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ABSTRACT

Strategic environmental assessment (SEA) is a process that aims to integrate environmental considerations into the formulation and implementation of plans, policies and programs. The aim of this paper was to highlight the importance of SEA in policy making process of Pakistan. The objective of this research was to undertake a strategic environmental assessment (i.e., to assess the environmental impacts) of the policy to introduce a participatory irrigation management (PIM) in Sindh province. The policy was designed in 1997, and first implemented in Sindh in 2002. The objective of this research was accomplished by carrying out comparative analysis in which two canals were selected, one with PIM and one without PIM for the assessment. Water availability, groundwater level, waterlogging & salinity and number of trees on canals were used as environmental indicators. The results reveal that the conditions are still same, and no significant improvements have been observed in the environmental indicators in the areas with PIM.

Introduction

Strategic environmental assessment (SEA) is a process that used to assess the environmental impacts of the proposed policy, plan, and program and integrate environmental considerations at the point of decision making. Strategic environmental assessment is a diverse field and have numerous applications in the various sectors such as water, land-use, transport, solid waste and forest, etc. In the water sector, SEA has been used in the planning of water resources, development of water policies, water related legislations, and master plans of energy or irrigation, etc. The importance of SEA in water sector has been identified through the legislations such as SEA Protocol (2003) and European Commission directives (2001). In Pakistan, SEA has not been transposed into national legislation (Victor & Agamnthu, 2014) except the Baluchistan Province (GoB, 2012). However, several studies have been done with use of SEA in Pakistan such as SEA of AJK hydropower development in 2014, SEA of master plan for Gilgit city in 2014, and so on (Huang et al., 2016).

The purpose of this study is to highlight the importance of SEA in policy making process of Pakistan especially in the water sector. The objective of this research is to undertake a strategic environmental assessment (i.e., to assess the environmental impacts) of the policy to introduce a participatory irrigation management (PIM) in Sindh province. The policy was designed in 1997, and first implemented in Sindh in 2002. Participatory irrigation management (PIM) is defined as an approach in which all beneficiaries are involved in decision-making process to improve efficiency, effectiveness, equity and cost-effectiveness of the irrigation system.

After 15 years of implementation of PIM in Sindh Province, this research aims to find the environmental impacts of the irrigation policy at the user level. In this regard, following parameter/indicators are assessed:

a) Water availability on farms/fields
b) Groundwater level
c) Waterlogging & Salinity level
d) Use of Fertilizers and Pesticides
e) Number of trees on the banks on canals/minors
f) Source and Quality of drinking water
g) Common Diseases
h) Water-related Conflicts
i) Abiana Rates

Literature Review

Strategic Environmental Assessment

Strategic environmental assessment (SEA) is a process that aims to integrate environmental considerations into the formulation and implementation of plans, policies, and programs. It is also defined as a tool to assess the environmental consequences of future policies, plans, or programs, and thus to ensure that sustainability considerations are incorporated at the point of decision making. Sadler and Verheem, (1996) defined SEA as 'a systematic process for evaluating the environmental consequences of the proposed policy, plan, or program to ensure that they are fully included and addressed at the earliest stage of decision making on par with economic and social considerations.'

The term strategic environmental assessment was first used by Wood and Djeddour in the late 1980s (Tetlow & Hanusch, 2012). It is built upon the related concept of environmental impact assessment (EIA), which pertains to a similar assessment of the environmental impacts of projects, and was first introduced in 1969 in the United States of America through the National Environmental Protection Act (NEPA). In the 1980s, world donor agencies such as the World Bank, the Asian Development Bank, and the OECD, as well as other financial organizations began to emphasize the preparation of SEAs and started to provide training on the SEA in developing countries. In 1992, the United Nation Conference on Environment and Development (UNCED) and Rio Declaration provided further impetus for national governments to incorporate environmental consideration into all levels of decision making. In 2003, SEA protocol was signed at the conference in Kiev, Ukraine.

Strategic environmental assessment is a diverse field and has numerous applications in the various sectors such as water, land-use, transport, solid waste, and forest, etc. In the water sector, SEA has been used in the planning of water resources, development of water policies, water-related legislation, and master plans for energy or irrigation, etc. The importance of the SEA in the water sector has been identified through the legislation such as SEA Protocol (2003) and European Commission directives (2001).

The current reviews about SEA effectiveness are showing mixed results. In - United Kingdom Poland and Portugal, SEA only leads to minor changes to planning content in various sectors. On the other side, SEA practice across the European Member States is largely effective. It not only integrates the environmental considerations into decision making but also become a basis to amend the plans and programs. In South Africa, SEA has been unsuccessful to affect the decision-making of PPP. To conclude, there is no one size that may fit all SEA features (Tetlow & Hanusch, 2012).

Strategic Environmental Assessment In Pakistan

In Pakistan, the laws and regulations of environmental assessment are present in the shape of Pakistan environment protection act (PEPA), EIA guidelines (PAK-EPA, 1997) and EIA regulations (PAK-EPA Regulations, 2000). In 2010, after the eighteenth amendment in the constitution, the subject 'environment' is legislated by the provincial governments. On the other side, SEA has not been transposed into national legislation (Victor & Agamnthu, 2014) but one of its provinces namely Baluchistan has made SEA as a mandatory for plans and programs (GoB, 2012).

Several studies have been done with the use of SEA in Pakistan (Huang et al., 2016) such as Pakistan strategic environmental assessment in 2006, mainstreaming environmental sustainability into industrial development in 2012, a SEA of AJK hydropower development in 2014 and SEA of the master plan for Gilgit city in 2014. These all practices and developments in the field of the SEA have been due to rise in public awareness and debate countrywide after 2004.

Participatory Irrigation Management

Participatory irrigation management (PIM) is an approach in which beneficiaries are involved in the decision-making process to improve efficiency, effectiveness, equity, and cost-effectiveness of the irrigation system. The concept of the participatory approach in irrigation is quite old. The new era of PIM began after the development of large-scale irrigation systems which are managed by bureaucracies through established formal institutions. When the management system failed to respond the needs of users and merely operation & maintenance (O&M) of the system lead towards the deterioration of irrigation systems then under these circumstances, the donor agencies like World Bank and Asian Development Bank introduced the concept of PIM in the 1980s (Kulkarni et al., 2013).

Historically, local or federal governments have managed the irrigation systems around the world. However, in present times the trend is - changing and countries are shifting their powers to water users or farmers organizations. The effectiveness of PIM has mixed results; both success stories and unresolved issues exist. The percentages of world's irrigation schemes managed by the government, joint ventures by private and public sectors and private are 39%, 1%, and 38% respectively, and about 22% of the schemes are unclear (Ghumman et al., 2014).

Participatory Irrigation Management In Pakistan

The background for the PIM in Pakistan was the low efficiency in irrigation system due to inadequate maintenance, insufficient cost recovery, and low productivity. Poor management of water resources had worsened the condition through non-availability of water during critical periods of crop growth. Also, the gap between the cost recovery and O&M cost had been widening over the time. For instance, in 1990, the revenue collected from water charges only paid the 44% of O&M expenditure of irrigation system (Khan et al., 2007). To manage all above issues, the government of Pakistan under the influence of donor agencies such as the World Bank and the Asian Development Bank introduced the participatory irrigation management in the country. This was formally initiated with the establishment of provincial irrigation and drainage authorities (PIDAs) through the enactment of the Provincial Irrigation and Drainage Authority Act in 1997. As a result of the Act, the Sindh Irrigation and Drainage Authority (SIDA) was established in 1998 followed by one Area Water Board (AWB) on the Nara Canal in 1999. Since then AWBs have been established on Ghotki Feeder and Fuleli/Akram Wah canals. The responsibility of PIDAs is to manage the irrigation system from barrage to primary canal level and drainage system from the main drain to major drainage basins. The intention of PIM initiative was to actively involve farmer's organizations in routine canal operations and maintenance as well as in the collection of irrigation and drainage service charges to achieve sustainable O&M of canal irrigation systems (Akhtar and Cepiku, 2013; Anwar et. al., 2008; Memon et al., 2001).

In Sindh Province, the SIDA (Sindh Irrigation and Drainage Authority) Act did not fully represent the spirit of the reforms and ensured a perpetual dominance of the irrigation bureaucracy on the new entities. This situation led to a massive introspection of the SIDA Act and culminated in the promulgation of the Sindh Water Management Ordinance 2002 aiming to accelerate the pace of reforms (Memon and Mustafa, 2012). The Sindh Irrigation and Drainage Authority (SIDA) was reconstituted in 2002. The decision-making structure of SIDA consists of four tiers of participatory bodies, namely the governing body, the area water boards, farmer's organizations, and watercourse associations, which are supported by the SIDA secretariat. The role of SIDA is to manage the water and maintain irrigation structures at primary canal levels.

Research Methodology

The objective to undertake the strategic environmental assessment (i.e.: to assess the environmental impacts) of Participatory irrigation management (PIM) in Sindh Province is accomplished by carrying out the comparative analysis. In this regard, two canals are selected one with PIM and one without PIM for the assessment. Then, from these two canals, two minors are randomly selected for the assessment. The data is collected at the head and tail of both minors through questionnaire survey. Then, the data analysis is performed in the Excel. The flow diagram of methodology is shown in figure 3.1.

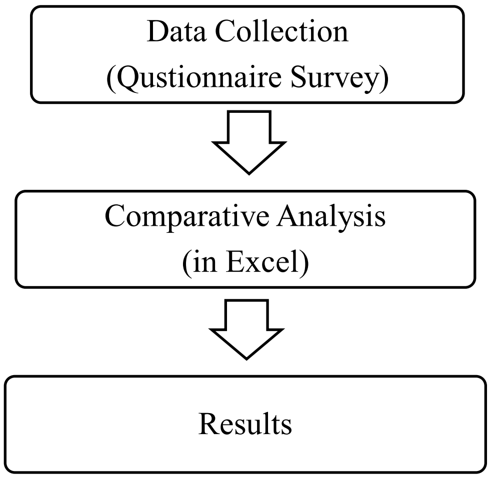

Figure 3.1: Flow diagram of methodology

Area of Study

This study assesses the two canals of Sindh Province through comparative analysis, i.e. Akram Wah and KB Feeder (Figure 3.2). Akram Wah is managed by SIDA (Sindh Irrigation & Drainage Authority) with PIM approach, whereas, KB Feeder is managed by Sindh Irrigation Department without PIM approach. Then, two minors were randomly selected namely Khairiyari Minor and Jam Wah minor from Akram Wah and KB Feeder respectively.

Akram Wah and KB Feeder are off-taken from the Indus River at kotri barrage. However, Akram wah offtake from the left side and KB feeder on the right side of the barrage. Both canals are perennial canals (flow 12 months). The design discharge capacity of Akram Wah and KB Feeder is 3713.65 cusecs and 9100 cusecs respectively. The culturable command area of Akram Wah and KB feeder is 532311 acres and 603000 acres respectively.

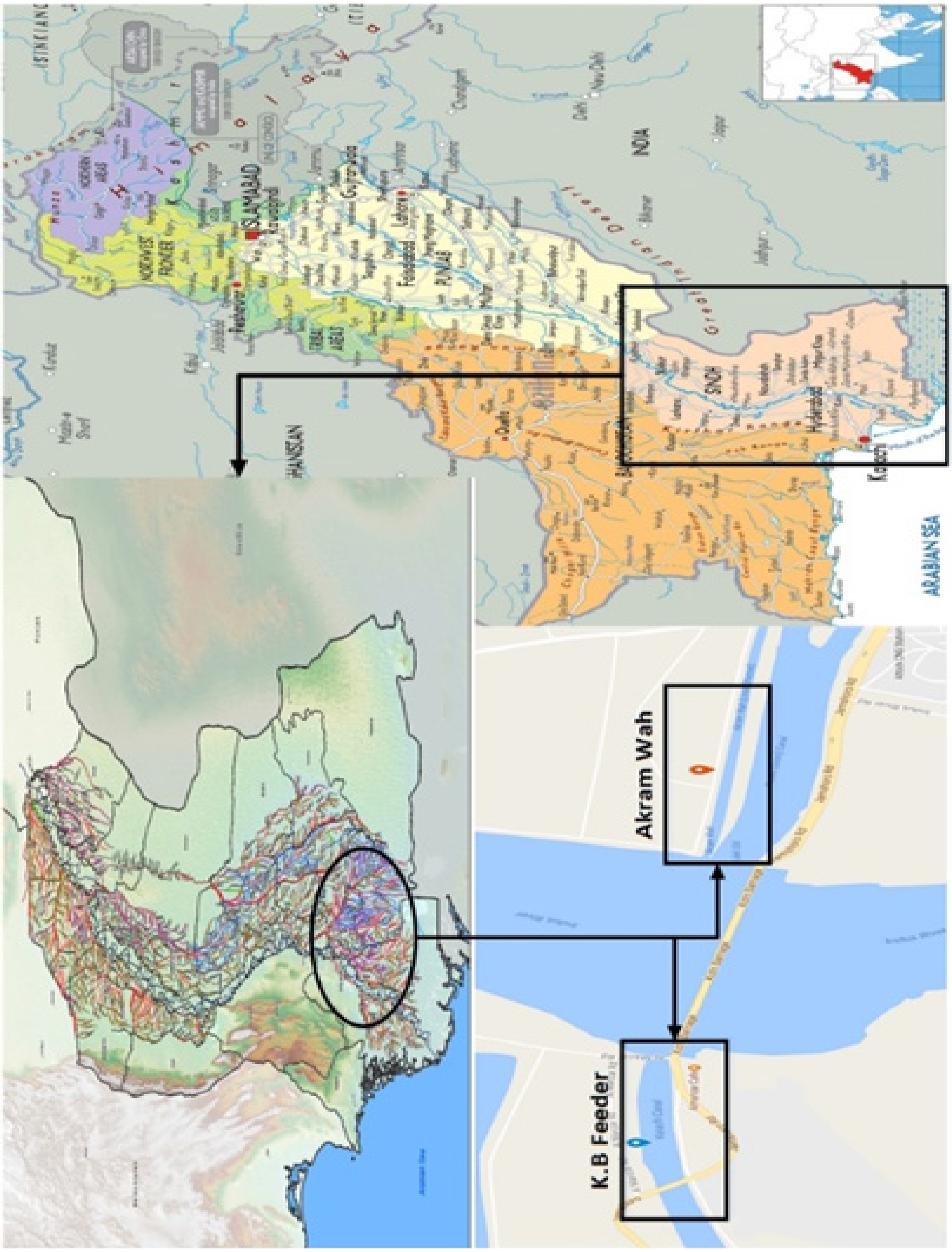

Figure 3.2 Map of study area.

Photograph 3.1 Jam Wah at Head (KB Feeder)

Photograph 3.2 Khairiyari Minor at Head (Akram Wah)

Data Collection

The data of environmental indicators were collected via questionnaire survey. These surveys were conducted at the heads and tails of the Khairiyari minor and Jam wah minor. The total number of participants in the survey was 100. All participants were belonging to agriculture occupation. Most of them were farmers and few were land owners. The questionnaire was designed into two parts. The first part was about personal information and general water related questions. The second part of questionnaire was consisting of environmental assessment questions.

Photograph 4.1 Interviewing participants at Jam Wah.

Photograph 4.2 Interviewing participants at Khairiyari Minor.

Results & Discussion

Water Availability

The water availability at the heads of both minors is 100% satisfactory. However, at the tail end, the satisfactory level for water availabilty has been reduced to 45% (see figure 5.1). The major causes for the reduction in satisfaction level at the tail end are the shortage of water and unavailabilty of water on required time. These are due to the following reasons:

- Tempering of moghas at the head
- Lifting of water at the head (Water theft)
- Poor operation and maintenance practices
- Blockade\obstascle at the head of minor to divert water

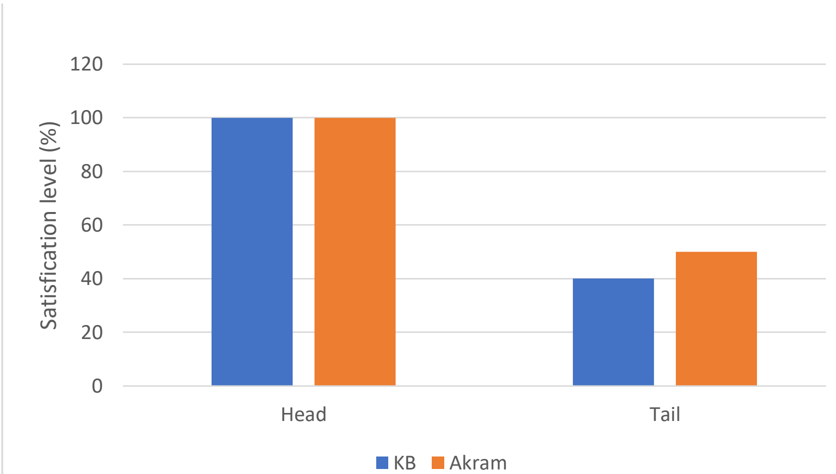

Figure 5.1 Water Availability

Groundwater Status

The groundwater on the both minors of KB feeder and Akram Wah is saline. Due to saline in nature, it has not been used for agricultural activities. There is no use of any tube-well for irrigation purposes. All the agriculture on both minors is dependent on the surface water. The majority of respondents are of the view that there is no difference has been observered with regard to groundwater in last five years (see figure 5.2).

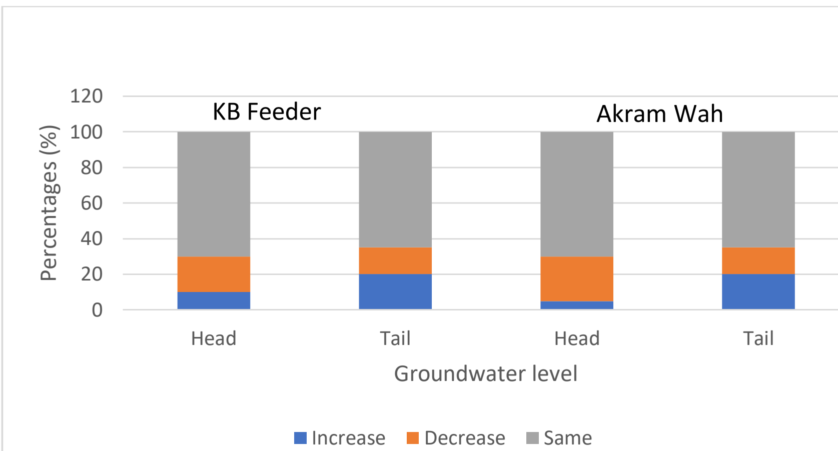

Figure 5.2 Groundwater status

Waterlogging and Salinity

The status of waterlogging & salinity on both minors have slight fluctuations (figure 5.3). However, more than half of the respondents are of the opinion that there is no significant changes have been obseved in last 5 years. Remaining respodents think that there are minor fluctuations in the waterlogging conditions with respect to seasonal variations. Furthermore, the decresing trend in the tail end areas are due to the shortage of water as compared to the head land areas.

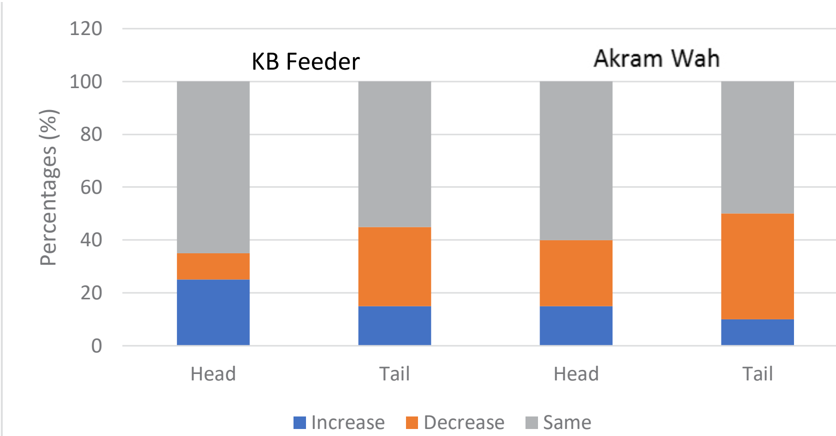

Figure 5.3 Waterlogging & Salinity

Use of Pesticides and Fertilizers

The 100% consences is observed in the increased used of pesticides and fertilizers in the agriculture on both minors (Figure 5.4). Furthermore, the croping and irrigating method used in both minors are almost same. They are using traditional methods for croping and flood irrigation method for irrigating purposes respectively.

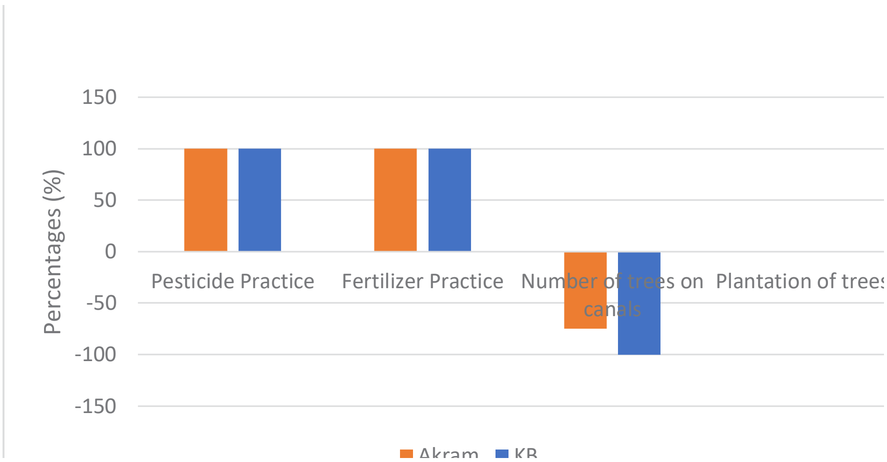

Figure 5.4 Pesticides, Fertilizers and Trees statistics

Trees on Canal/Minors

On the Jam Wah minor, all participants are of the view that there are no trees left on the banks of the minors as compared to last 10 years. Whereas, on the Khairiyari minor, all participants are of the view that only 30% of the tress are left as compared to last 10 years. The deforestation arises as the one of the big menace on both minors.

Plantation of Trees

In figure 5.4, an alarming situation come to know that there is no plantation of trees has been done by the government or by the community in last 5 years on both minors.

Sources and Quality of Drinking Water

The sources of drinking water on both minors Khairiyari and Jam wah are groundwater and surface water (see table 5.1). Majority of the people on both minors think that the quality of drinking water is satisfactory. However, few respondents from Jam Wah (KB Feeder) complain about the quality and stated it as poor. They further expressed that the groundwater is saline and surface water is turbid, which are not consumable for drinking as well as domestic purposes without any treatment. The common methods used for the treatment of water by the residents are sedimentation, boiling of water and use of Alum commonly known as Phitki.

Common Diseases

The common diseases on both minors are Malaria, Diarrhea, Hepatitis and Cholera (see table 5.1). Most of them are water borne diseases. All the respondents were agreed that the frequency of diseases in residents has been increased.

Conflicts

No major conflict has been witnessed on both minors in last year. But, few small disputes have been reported at the tail-end of Jam Wah (KB Feeder) with no major loss (see table 5.1). These disputes are usually resolved by the community within 72 hours. The major cause of disputes in the tail-end area is the uneven distribution of water among shareholders, during shortage of water.

Abiana Collection Rates

The term "Abiana" is defined as the water tax. The abiana is collected by a government employee, commonly known as 'Tapedar'. According to the respondents, the abiana rates are not fixed. The true rates of abiana are not disseminated to the farmers and landowners by Tapedar. Most of the respondent are of the view that they are being charged more than the abiana taxes. This claim appears to be right when it was compared to the government's water charges (see Table 5.2). Talking about PIM performance as whole in Sindh Province with respect to Abiana recovery, it disappoints by collecting only an average 38% of assessed Abiana during 2003-04 to 2009-10 (Planning commission, 2012).

Table 5.1 Environmental Parameters

Sr. No.	Parameters	Jam Wah (KB Feeder)	Khairiyari Minor (Akram Wah)
1.	Source of drinking water	Groundwater, Surface water	Groundwater, Surface water
2.	Quality of drinking water	Satisfactory	Satisfactory
3.	Diseases	Malaria, Diarrhea, Hepatitis, Cholera.	Malaria, Diarrhea, Hepatitis, Cholera.
4.	Frequency of Diseases	Increased	Increased
5.	Irrigation Method	Flood irrigation	Flood irrigation
6.	Cultivation Method	Traditional method	Traditional method
7.	Number of Conflicts	4 (minor)	No
8.	Loss due to Conflicts	No major loss	No major loss

Table 5.2 Abiana Rates per Acre

Sr No.	Crops	Jam Wah (avg. rate charged by Aabdar in Rupees)	Khairiyari minor (avg. rate charged by Aabdar in Rupees)	Government Rates* (in Rupees)
1.	Rice	500	500	89
2.	Wheat	300	250	53
3.	Sugarcane	NA	1000	182

Conclusion

The results reveal that the conditions are still same, and no significant improvements have been observed in the environmental indicators in the areas with PIM. The water availability at the tail-end of both minors is unsatisfactory due to the poor operation & maintenance, tempering of moghas (outlets) at the heads, water theft and lifting of water. Groundwater is saline and not fit for the agricultural and domestics purposes. There is no noteworthy threat observed with respect to the groundwater exploitation. As for as waterlogging & salinity is concerned, minor fluctuations are being observed due to the seasonal variation of crops. The waterlogging & salinity problem is at moderate level on both minors. The major concern on both minors is the absence of drain system, which is used to control the waterlogging & salinity problems.

Talking about the pesticides and fertilizers, the significant increase in usage has been reported in agriculture on both minors over last five years. On the other side, the number of trees on the banks of canals/minors has been significantly decreased. Furthermore, no plantation of trees has been started on both minors in last five years. The disinterest for the plantation of trees by the government shows their non-seriousness towards the environment aspect of PIM Policy. If the actions will be not taken on time, the ecological balance will be disturbed.

The sources of drinking water in both minors are groundwater and surface water. Majority of respondents are satisfied with quality of drinking water. For them, the quality of water is the only matter of taste and colour. However, both sources can be vulnerable and unsafe for drinking and domestic purposes. Most of common diseases are identified as water borne diseases such as Hepatitis, Diarrhea, Cholera, Malaria and Fever. The increase in frequency of diseases over past years possess a major threat to the neighborhood. The socio-economic conditions of the farmers and small growers are not satisfactory. Majority of small farmers (have less than 5 acres) are under the poverty line. Their socio-economic conditions are totally dependent upon the water via agriculture.

Suggestions

This research suggests the policy-makers to the following:

1. To practice strategic environmental assessment in the making of new policies related to natural resources specially water resources in the Sindh Province.
2. To conduct strategic environmental assessment of upcoming water policy in Sindh Province.
3. To start plantation on the banks of canals/minors on immediate basis in order to safeguard the ecological balance.
4. Provide safe drinking water in rural areas, in order to prevent the residents from water borne diseases.

Future Research Recommendation

1. To conduct strategic environmental assessments of available plans, programs and policies in any sector of Sindh Province.
2. To conduct drinking water quality assessment in the rural areas of Sindh Province especially in the neighborhood of Jam Wah and Khariyari Minor.

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NEXUS APPROACH TO ADDRESS WATER-ENERGY-FOOD SECURITY OF PAKISTAN

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ABSTRACT

Pakistan is facing serious challenges of environmental degradation and natural resources scarcity such as water, due to rapid rise in population and climate change. Countries such as Pakistan have devised policies to increase production of cereal crops by providing subsidies on water and energy in agriculture sector. This policy has resulted in overexploitation and degradation of the natural resource base such as groundwater. This approach has not only exerted unsustainable pressure on resources but has also led to under investment in technologies which will conserve water and energy while meeting the increased demand at the same time. The usual fragmented approach of various organizations involved in water-energy-food sectors has threatened achievement of sustainable development goals. A nexus approach is therefore required to decouple intensive use of water and energy for increased food production. The intricate nature of water, energy and food requires holistic approach to develop synergies and avoid tradeoffs in the nexus. This research presents a conceptual framework for water, energy and food nexus, identifying the key driving parameters in each sector and coupling parameters between these three sectors. Here, we present a conceptual model consisting of causal loop diagrams with feedback loops which will be utilized in developing a nexus framework to address WEF security of Pakistan.

Keywords

Water-Energy-Food (WEF) nexus, feedback loops, framework, security.

Introduction

Adequate water resources, affordable energy and access to food are vital for the social and economic wellbeing of a society. Today, climate change and rapid rise in global population has led to degradation of water resources and insecurities of food and energy. Current global population is projected at 7 billion (United Nations), catering the needs of which is a challenge. Meeting the needs of

increasing population sustainably under the stress of climate change requires holistic approach, augmenting concepts into policies which focuses on building synergies and avoiding tradeoffs. Problems concerning interrelated sectors such as water, energy and food put a tremendous burden on the survival of a society thus, it is the collective responsibility of human society to rise to the challenge of addressing these problems effectively [1].

Concept of WEF nexus was first presented in a conference held at Bonn in 2011 and it was given paramount importance in "The future we want" declaration of Rio 20+. United Nations has also embraced the vitality of nexus concept by incorporating nexus approach in realizing the achievement of sustainable development goals (SDGs).

The convoluted nature of WEF has complicated addressing supply risks arisen due to population rise and climate change, because intervention in one sector impacts other sectors [2]. Sustainability is compromised when tradeoffs are not taken into consideration. Both political and economic challenges have come up due to various limitations encountered due to intricate nature of these three sectors [3].

Though exact definition of nexus is not agreed upon but the key concepts remain consistent in literature. Focus of nexus is to increase economic benefits without compromising the viability of ecosystem resources [4]. Conventional approaches deal with maximizing output without taking into consideration the associated externalities thus, nexus can play vital role in addressing these discrepancies.

Planning Commission of Pakistan has forecasted current per capita water availability at 1000 m3/year which is the dividing line between water stressed and water scarce conditions. Below 1000 m3/year per capita water availability according Falkenmark water security index shows scarcity. Food & Agricultural Organization (FAO) statistics show that during the period of 1950-2012, population of Pakistan rose from 40 million to 173 million and is projected to reach 237 million by 2025. While demand is increasing, supplies and infrastructure is inadequate to cope with increasing demand. An increase of 48.3% is predicted in agriculture water demand by 2025 reaching to water consumption of 349.2km3 [5].

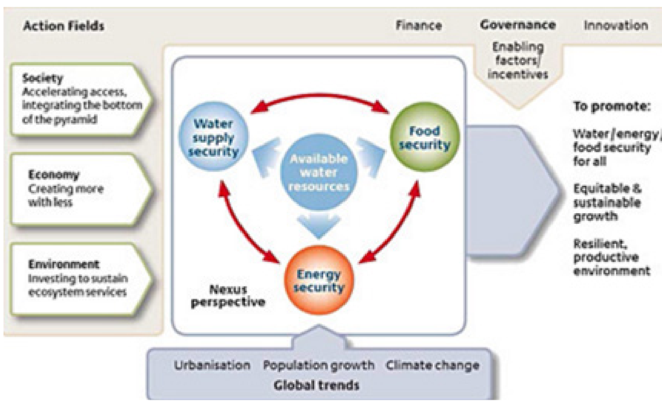
Decrease and non-availability of surface water throughout the seasons have provided the stimulus for increased use of groundwater leading to overexploitation of this limited resource. In 2012, FAO calculated groundwater extraction rate at 60km3 which is greater than the annual recharge rate of 55km3. Almost half of the current irrigation requirements are met by groundwater. Over the last 15 years, crop production on average increased by 3% but the increase in energy intensity was 80% [6]. Major portion of energy usage in agriculture sector comes from direct energy use in the form of diesel and electricity consumed in pumping. Conventional irrigation practices such as basin and furrow irrigation are usually employed. Both water productivity and water efficiency are low compared to neighboring countries such as India.

Another serious implication of intensive water use is decreased supplies to sustain the ecosystem of natural water bodies like rivers. Downstream impacts include sea intrusion and salinity problems in adjoining areas. This is one of the most important aspect of implications when nexus approach is not employed. Intensive irrigation to increase food demand at the cost of increased water usage and downstream areas degradation leads to long term unsustainability.

In this research, an attempt has been made to link different variables in agricultural WEF nexus at national level to explore tradeoffs and synergies. A framework for WEF nexus has been presented and variables in the nexus have been linked using causal loop diagrams with feedback systems

Methodology

The scope of this research is to explore WEF nexus at national level with particular emphasis on agriculture sector of the country. Available literature was surveyed in which different frameworks of WEF nexus for different spatial scales and at different policy levels were observed.



Source: Bonn2011 conference: The water, energy and food security nexus.

The above framework is used as a guideline to develop framework relevant in the context of Pakistan. As it is evident from the framework, water resources are placed at the center showing its importance with respect to all other variables in the system. Food and energy are users of the water resource thus, ultimately it all comes down to availability and sustainability of water resources.

Water use and energy data was obtained from FAO and agricultural statistics of Pakistan respectively. Water use data for municipal and agriculture sector was obtained from AQUASTAT database of FAO while tube wells data was obtained from agricultural statistics of Pakistan. Energy costs in agriculture sector from using pumping was obtained from available literature.

Once the framework and data is visualized, we turned our focus to establish connections and directions of flows in the system. Important aspect of this part is that it does not only show connections among different parameters but it also gives us an understanding of the feedback mechanisms and polarities among the parameters.

Causal loop diagrams were developed to show feedback processes in the agricultural WEF nexus relevant to the case of Pakistan. Causal loop diagram consists of nodes and edges with nodes representing the variables in the system while edges representing connection/relation among the variables. Nodes are assigned name such as food production and then are connected with variables such as crop land area using edges (arrows).

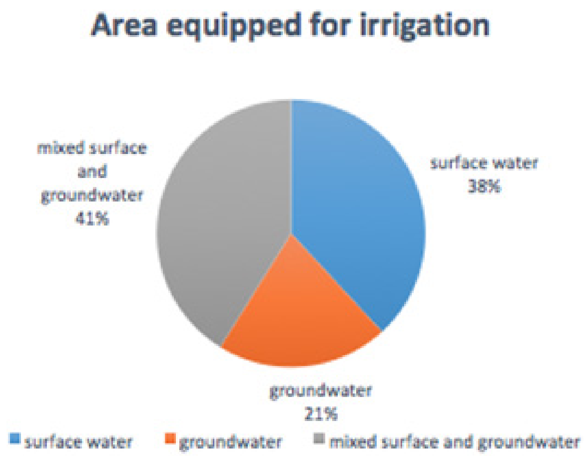
All natural systems are non-linear which means they have feedback mechanisms. Outputs of a system in turn influences inputs into the system. WEF nexus is also a non-linear system interacting in a complex way. Causal loop diagrams are built showing connections in the system. Important aspect is the polarity which indicates whether an increase in one variable will increase another or vice versa. Arrowheads indicate the direction and causality in the system.

Both the framework and causal loop diagrams indicate tradeoffs and synergies in the system and from this model, identification of undesirable behavior in the system is possible.

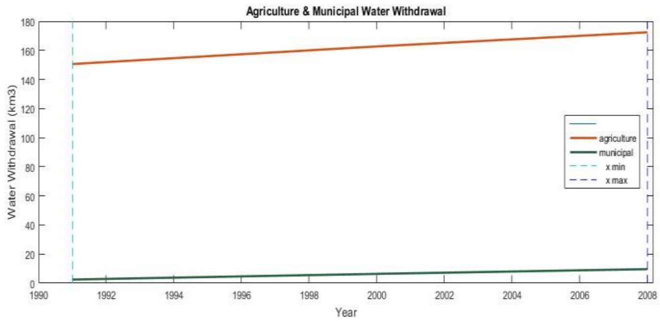
Model

Data Visualization

Area irrigated by different water sources in Pakistan is shown below:



Total equipped area for irrigation in Pakistan is 19990000 hectares out of which 4130000 hectares is irrigated by groundwater and 8230000 hectares is irrigated using mixed surface and groundwater. This shows that the agriculture sector of Pakistan is highly energy intensive as the major portion of direct energy consumption comes from groundwater pumping. Farmers are shifting to groundwater which is more reliable water source compared to surface water, availability of which is uncertain. Also, it is a known fact that efficiency of surface water usage is low and that deficit in then compensated by exploiting groundwater resource.



Food & Agricultural Organization has published online data of different sectors such as agriculture and municipal. Here we do not take industrial water withdrawal into consideration because it is a minor portion of total water withdrawal. As the graph shows, demand of both municipal and agriculture sector is increasing. In 1991 agriculture and municipal withdrawal was 150.6 km3 and 2.5 km3 while in 2008 this withdrawal reached 172.4 and 9.65 km3 respectively. Agriculture demand increased by 12.64% while municipal demand increased by 74.1%. Such a high increase may be attributed to rapid population growth and urban migration where per capita water demand is higher that rural per capita water demand.

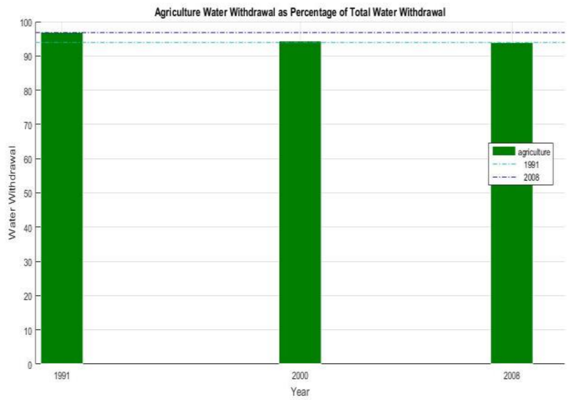


FIGURE 3

Though the share of agriculture water withdrawal in total water withdrawal has decreased over the period, still it is the major consumer of water resources with around 90% water withdrawal of total water withdrawal. The percentage has decreased from 96.79 in 1991 to 93.95 in 2008. According to estimates and available literature, current consumption remains around 90%.

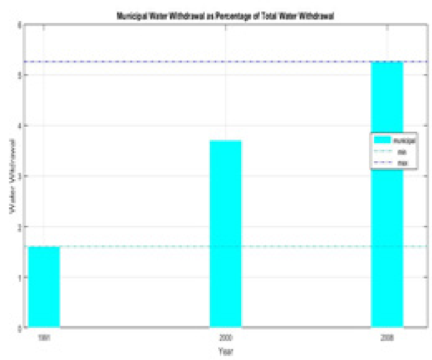


FIGURE 4

Similar data was plotted for municipal demand to compare with agriculture demand as we are also trying to evaluate competition among sectors to address tradeoffs and adopt synergies. In 1991, municipal water withdrawal

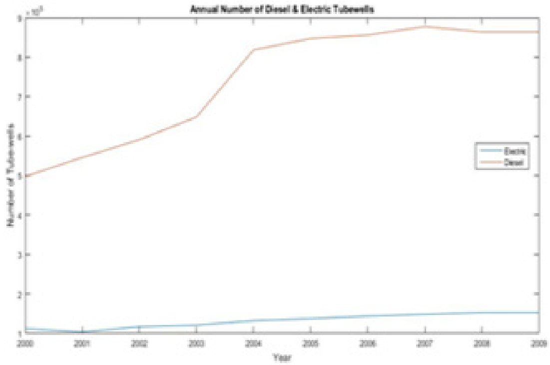
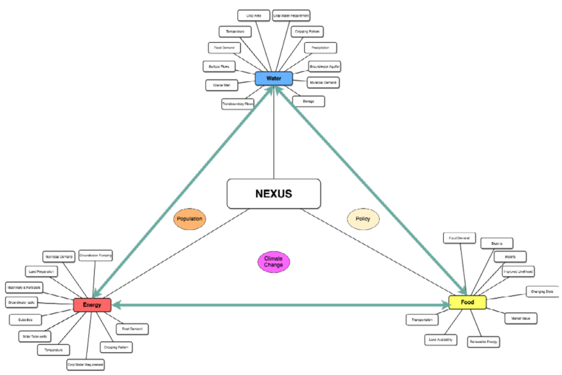


Figure 5

As already discussed before, agriculture sector of Pakistan is energy intensive. Major portion of energy comes from groundwater pumping and it is due to the inefficiencies in the irrigation techniques and variability in water availability that farmers use groundwater. The data shown here is taken from agriculture statistics of Pakistan. It shows number (annually) of tube-wells operated on electricity and diesel. As lines show increase in number of tube wells and diesel tube-wells increase more rapidly than electricity tube-wells due to the fact that smaller farmers cannot afford to buy a connection for electricity which includes transformer and other miscellaneous charges and because majority of farmers in Pakistan are poor hence, more number of diesel tube-wells. Furthermore, these numbers show both private and government installed tube-wells. The distribution of tube-wells installed at varying depths is shown below [7]:

Diesel		**Electric**	
< 30m	55%	< 30m	40%
30-45m	30%	30-45m	20%
46-75m	10%0	46-75m	30%
> 75m	5%	>75m	10%

Average fuel consumption of a diesel tube-well is 1.5-2.5 liters/hour and electricity units consumed by a 10hp tube-well is 8/hour [7]. Horsepower vary with depth, deeper water tables require more horsepower and also consumption vary accordingly for both diesel and electricity tube-wells.



WEF Nexus Framework

Three external drivers namely population, climate change and policy interventions are mentioned here which drive the WEF nexus. The framework shows different parameters linked to different sectors and also parameters, which are common. Two headed arrows show interdependency among sectors. Increase in per capita food demand will increase the total food demand and agricultural water demand. When population is increasing, food demand does not only exert pressure on agriculture sector in terms of more water withdrawal but municipal demand is also increased thus, increased supplies to irrigation will compromise supplies to domestic water demand. This is why nexus approach has advantage over fragmented approach which is based on silo thinking. Controlling population growth, mitigating impacts of climate change and devising policies which are beneficial across all the sectors will drive the nexus towards sustainability.

Causal Loop Diagram

CLD showing feedback mechanisms in the system

The parameters included here in the model are placed keeping in view the future application of this framework in developing stock-flow model which is the second stage of this research. Many parameters in the future stock-flow model will not be quantified nevertheless, there impacts on the system can be evaluated from this causal loop diagram. Feedback mechanisms are visible such as interaction between crop land area and crop market price. Interaction between crop land area and seawater intrusion is also a feedback process. The diagram shows the whole system of agriculture sector and how different parameters interact with each other. This model focuses on consumption side in WEF nexus which means that it incorporates parameters which control the consumption of water, food and energy in agricultural WEF nexus of the country.

Discussions

Long-term sustainability requires policies that are aimed to foresee future challenges and competition among sectors. While there have been numerous reports and publications about water security and agriculture sector sustainability in Pakistan, an official approach at the organizational level for WEF nexus is missing. Planning Commission of Pakistan in 2013 published a document outlining goals for economic and social development of country and the document was termed as Pakistan Vision 2025 in which fourth pillar out of total seven pillars, talks about WEF security. But there is no realistic mechanism for achieving ambitious goals that are outlined in the vision. Again nexus thinking is missing without which tradeoffs develop and sustainability is compromised. As already discussed in the framework section how change in one variable affects other variables in the system. We saw increase in water withdrawal for both agriculture and municipal sectors, but water flows remain the same or decrease overtime. Such situations warrant policies which can develop acceptable outcomes for all sectors and it is possible only through adaptation of nexus thinking at planning and policy levels. Here, we focused the scope of this study to analyze agriculture sector in detail while neglecting energy demand in domestic and industrial sector which is not the scope of this research. But demand is increasing across all the sectors and synergies need to be built to satisfy demand of each sector.

Again coming back to the agriculture sector, energy consumption is split into direct and indirect. Direct energy comes from pumping while indirect energy comes from fertilizers, pesticides and machinery etc. Per hour operating cost of diesel and electric tube-well is Rs. 173 and Rs. 138 respectively while a solar tube-well costs Rs. 83 per hour of operation. As the data above showed continuous increase in number of tube-wells, it is evident that cost is also increasing continuously. Moreover, diesel tube-wells are more in number and Pakistan imports much of its consumption requirements of fuel thus, it exerts a security threat on agriculture sector as oil supplies cutoff will affect agriculture sector and food production.

Conclusion & Recommendation

Water security problem in Pakistan stems from poor management of the resources rather than non-availability of supplies. Consumption is uncontrolled and population growth is not sustainable due to which demand is rising faster than the coping capacity. Agriculture consumes the major portion of annual renewable water supplies but it is not reflected in the economic output of the sector in GDP. The reason is low water productivity and inefficient irrigation techniques.

Through extension of this CLD, various scenarios can be tested to obtain the most desirable outcome. Scenarios can be based on varying population growth, improvement in livelihood, temperature changes and land competition. The purpose would be to determine the pathways of different policy interventions in reaching the desired goal of sustainability.

Some recommendations are given based on observed data and deductions:

- Increasing efficiency of irrigation system
- Shifting to renewable energy sources such as solar and wind
- Treatment of wastewater to reuse it for potable and non-potable purpose
- Using domestic wastewater for non-food crops
- Controlling population growth rate
- Devising strategies to mitigate impacts of climate change
- Inculcating nexus and sustainability thinking into policy level institutions of Pakistan

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TECHNO-FEASIBILITY ANALYSIS FOR HYDROPOWER GENERATION OF RD-26, NARA MAIN CANAL, SINDH

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ABSTRACT

Pakistan's hydel energy potential has escalated to 8000 MW having northern areas with major share and Sindh with minimal. For Sindh, the reason, for the absence of hydel energy, is the concept that it has plain terrain and not enough head for run of river projects. This study acts as a testimony for the availability of head as well as discharge enough to lit hundred houses. The present study has untapped 3.2 MW of electricity on Nara Main Canal at location, RD 26. RETScreen model was used to analyze the techno-feasibility of the electricity. The study concluded that at 11% inflation rate, 9% discount rate and 20 years of life span with 300 USD per kW and 25% sensitivity analysis, an average of 5000 MWh electricity can be supplied to grid.

Keywords

RET Screen, Hydropower in Sindh, Nara Main Canal (NMC), Reduced Depth (RD)

Introduction

Energy is an utmost outright need of world. The provision is significant to an extent that sacrificing health and environment has been a common practice.US Environmental Protection Agency claims that 65% of global greenhouse gas emissions are generated by fossil fuel combustion- major source of electricity generation [1]. From which, emission rate of coal, oil and natural gas is 45, 35 and 20 percent respectively [2]. Reason behind the massive use is either profuse availability or cheap cost. If only coal alone is considered, its cost is US$ 50 per ton and the pollution as well as increase in average atmospheric temperature that it creates is 4 times of actual cost [3].

Burning of fossil fuels is driving an increase in the Earth's annual average temperature. World is already aware of such conditions. In COP21, Paris, France, December 2015, the target was set out to cease the global rise of average annual temperature up to 2 degree centigrade. An analysis on the emission rates projects that European Union, United States and China would collectively emit about 21Gt CO_2e in 2030. In addition, based on current and planned policies as of late 2014, the rest of the world would collectively emit 35.4Gt CO_2e in 2030. This boils down

the total emission to around 57 to 59 Gt CO_2e in 2030 while it has to be between 32 and 44 Gt CO_2e in 2030 [4]. The awareness of risks, posed by using unconventional methods, is an alarming condition that is compelling world to switch towards renewable energy generation resources.

Renewable energy including hydropower, solar, wind, geothermal, and biomass, as they stand, supplies 22.8 percent of the electricity mix. The energy generation with hydropower (16%) is comparatively more than Solar and wind together (6.8%) [5]. With the recent developments, world hydro power capacity has now reached to

1000 GW, enough to provide renewable electricity to 1 billion peoples not to mention other services that it can provide like management of floods and droughts, ensuring and balancing clean and sustainable energy systems [6]. According to 2016 hydropower Status Report of IHA, two-thirds of the hydropower potential is still untapped , especially in developing countries while the installed capacity has reached to 1,211 GW offering low carbon supply to more than a billion peoples [7].

Pakistan, one of the developing countries, mainly depends upon the unconventional methods for energy consumption. Contribution of natural gas, oil, coal, hydro, nuclear and renewable resources is 50%, 30%, 8%, 11%, 0.9% and 0.1% respectively [7]. The per capita electricity consumption is 425 KWh whereas the world average per capita electricity consumption is approx. 2516 KWh-almost six times higher than that of Pakistan. Estimates indicate that the demand for energy would increase by three folds by the year 2050. While the supply trend, as it stands, is discouraging; being 40% short of the total demand [8]. As a result, approximately 60 million people and 40000 villages have no access to electricity [9]; more than 22 million electricity consumers are facing energy shortage. Energy shortage has been major culprit in worsening the socioeconomic conditions, GDP lost has already reached to 1.5-2%. Unemloyment rates are skyrocketing not to mention dramatic spreading of distress among citizens [9].

One of the major source to curb the electricity shortage can be hydropower potential since the river Indus traverses throughout the country. The potential for hydropower generation mostly resides in north areas while the south is scarce. It’s because the north is rich in natural and controllable waterfalls while south comprises plain terrain not to mention the tail end user.

Sind, being second largest province in terms of population, located in south of Pakistan, covers approximately 140,915 square km [10]. In Sind, wind farms have been constructed to harness electricity. According to Nepra report of 2013, 5 projects of about 255.34 MW are in operation, 9 projects have achieved financial close and are under construction, 11 projects are yet to introduce. In case of solar energy, many projects have been announced to supplement in power generation [11]. The case with hydropower energy is daunting; there hasn’t been a single implementation work on hydropower generation when in fact few potential sites have already been detected by Irrigation and Power development having 1115

The Irrigation and Power development, responsible for carrying hydropower activities in the province, has identified 6 sites that have potentialities of hydropower generation decades ago. These include Nai Gaj Fall, Indus/Nara Canal, Rohri and Guddu Barrage Projects. These projects have an estimated total capacity of 178 MW, with medium to low heads at different canals- range is in between 6-8 feet. Based on these heads there are chances of installing community based micro and pico hydro system-technology that was successfully adopted in Nepal [12]- that can generate electricity up to 5 KW, enough to illuminate 250 households with minimum requirements [13].

Raghunath Jha, researcher, has estimated the power potential and annual energy estimate on Run-of- River (ROR) basis of entire Nepal. His methodology considered hydrologic, GIS and Hydropower model analysis on three big rivers: Saptakoshi, Narayani and Karnali, and other small to medium rivers. The method has taken all the possible parameters in to consideration but the major constraint- also the contribution of the author- is that the he has automated own hydropower model [14]. In spain, for small hydropower assessment RETScreen software was used. This software give rise to hygrological analysis along with hydropower model. Interestingly it covers almost every parameter that Mr. Raghunath has inegrated in his model. In addition, it also considers Gross heads and losses along with flow rates in hydrological analysis.

RETScreen software is already imbibed with metereological data both ground-base and NASA’s satellite –derived and is freely available for 220 countries including Pakistan.

Furthermore, software predicts all the potential obstacles that can arise durng operation [15].

Therefore, this study will study the techno-feasibility of site regarding hydropower generation. The site is located at approximately 7.5 km downstream Nara Main Canal (NMC).

NMC is one of the seven canals that off-take from the Indus River at Sukkur Barrage. The reason for the site to be potential for hydropower is because it is a hydraulic control structure that has minimum of 200 cusec of water throughout the year not to mention the availability of head as shown in table 1.

Table 1: Input Parameters for Hydrological Model in RETScreen

Head water level (ft)	**196**
Tail water level at rated discharge (ft)	182
Gross head (ft)	10.2
Net head (ft)	9.7
Discharge (cusec)	2649
Residual Discharge (cusec)	200
Total Net Power Generated (MW)	15
Empirical Power Generation (output of RETScreen) (MW)	3.2

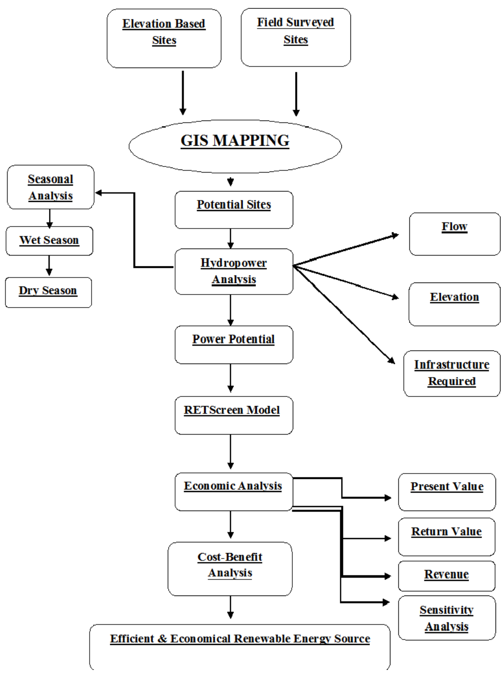
Table 2: Sites identified by Irrigation & Power Development Board (IPDB)

Project Name	**No. of Sites**	**Hydropower Potential (MW)**
Nai Gaj Fall Project	1	80
Sukkur Project	3	48.55
Guddu Barrage Project	1	33.5
Rohri Project	1	16

Objectives

- To analyze the hydropower potential for RD 26.
- Elucidate the financial viability of the potent site.

Methodology



The methodology of this study is as described below:

1. The sites are identified according to the head and discharge with the help of the formula described below:
2. The formula is just the attestation for presence of head; after that, the model is run according to input parameters as shown in Table 1 for hydrological analysis. The analysis is purely seasonal bifurcated in wet and dry seasons.
3. Then the model is run for financial analysis that includes the Internal Rate of Return (IRR), Net Present Value (NPV), and Sensitivity Analysis. The parameters that are varied in model for sensitivity analysis is flow adjustment factor and residual flow.

Results & Discussion

Energy Model

This step requires the collection of data in terms of site location i.e. latitude and longitude along with available head or drop in elevation as shown in figure # 1 & 2.

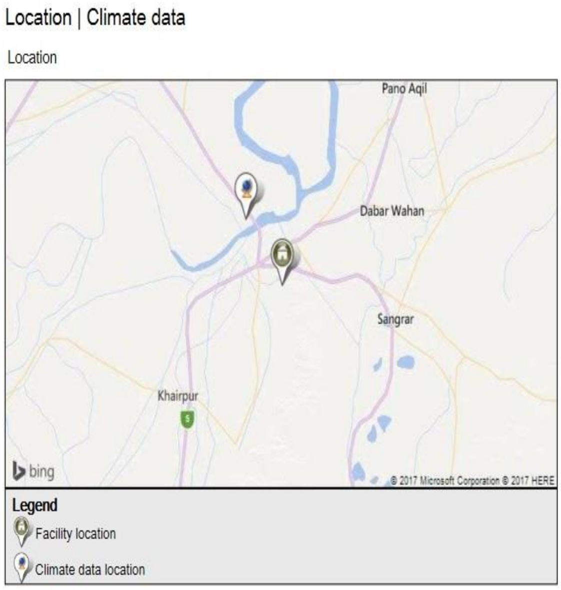


Figure 1: Satellite View of RD 26

	Unit	Climate data location	Facility location
Name		Pakistan - Sukkur	Pakistan
Latitude	°N	27.7	27.6
Longitude	°E	68.9	68.9
Climate zone		1B - Very hot - Dry	1B - Very hot - Dry
Elevation	m	51	0

Figure 2: Climate Data of RD 26

Hydrology Analysis & Load Calculation

This step was conducted with the aid of adjusted available flow throughout the year. The annual flow is then bifurcated in to wet and dry season hydrological analysis in order to have realistic approach for hydropower generation. The flow of June is taken for dry season while as the flow for month of august is considered for wet season. Apart from monthly available flow, model was heavily sensitive on flow adjustment factor that was kept 0.25 in order to have minimize the fluctuations between the available flows. The hydraulic losses were calculated as 7% followed by miscellaneous losses as 1%.

The flow duration curve (FDC) of RD 26 concludes to have 3 megawatt of power capacity along with an average of 5000 MWh electricity export rate as shown in figure 3. The export rate in dry season and wet season indicated fluctuations; however these fluctuations are minimal and can be avoided. The FDC of RD 26 has been calculated from data obtained from Sindh Irrigation and Drainage Authority. The residual flow was not obtained from SIDA therefore this study adopted conservative approach i.e. it considered the biological flow as residual flow i.e. 200 cusec as shown in Table 1. However, based on ground trothing and local knowledge; the residual flow would be maximum. The residual flow has a linear relationship between the power capacities so the more is better provided that it is available throughout the year even in flooding conditions.

Target

Summary

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	5,697	683,586	2,331

Figure 3: Summary of power generation

Dry Season

Losses			
Maximum hydraulic losses	%	7%	
Miscellaneous losses	%	1%	
Generator efficiency	%	93%	
Availability	%	95%	
Summary			Firm
Power capacity	MW	3.2	0
Available flow adjustment factor		0.25	
Capacity factor	%	20.5%	
Initial costs	$/kW	300	
	$	971,400	
O&M costs (savings)	$/kW-year	0.02	
	$	50	
Electricity export rate		Electricity exported to grid - monthly	
	$/kWh	0.12	
Electricity exported to grid	MWh	5,816	
Electricity export revenue	$	697,966	

Figure 4: Hydrological Summary in Dry Season

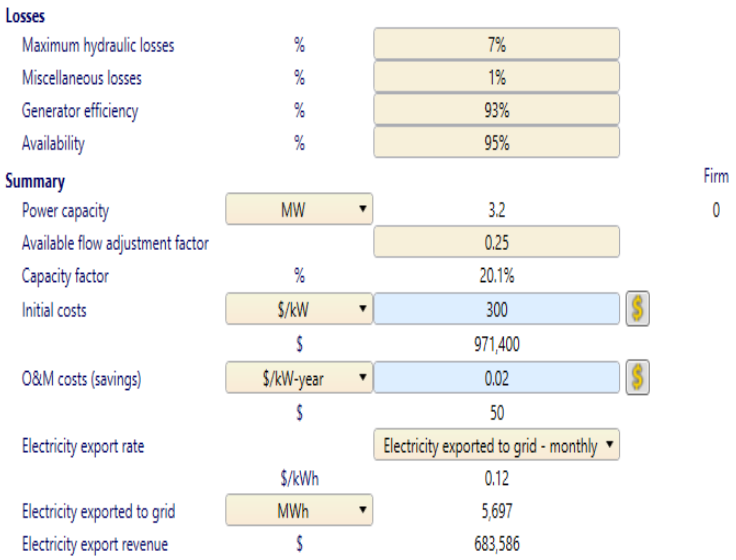


Figure 5: FDC of Dry Season

Wet Season

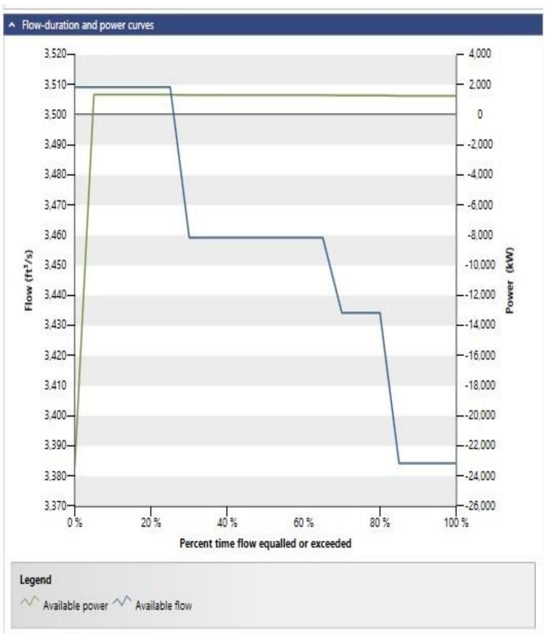


Figure 6: Hydrological Summary in Wet Season

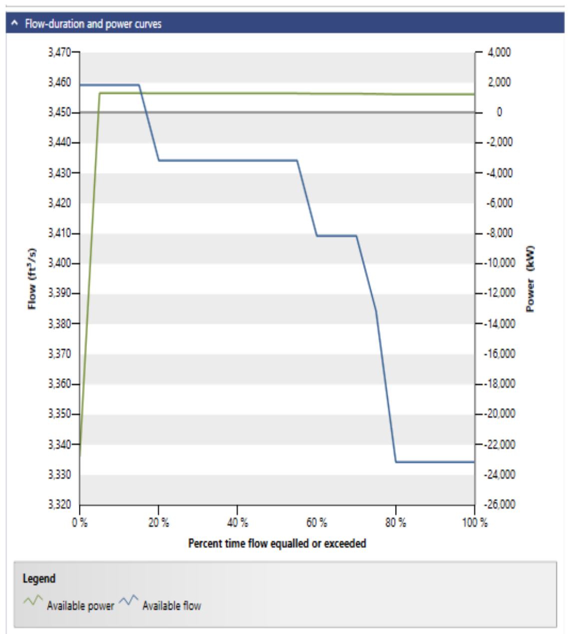


Figure 7: FDC of Wet Season

Financial Analysis

Various economic and financial feasibility indices were calculated such as year to year positive cash flow, Internal Rate of Return (IRR), return of investment (ROI) AND Net Present Value (NPV). The results are summarized in Table 3 & 4.

The accumulated cash flows over 20 years of operation with the debt term of 15 years as shown in figure 8. The model was given an initial cost of 300 USD/Kw based on the initial cost of turbine and infrastructures and allocating the equity as 25% along with inflation rate as 11% and discount rate as 9%.

Table 3: Financial Parameters of RD 26

Financial viability

Financial parameters

General		
Inflation rate	%	11%
Discount rate	%	9%
Project life	yr	20
Finance		
Debt ratio	%	70%
Debt	$	679,980
Equity	$	291,420
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	74,658

Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	5,697
Electricity export rate	$/kWh	0.12
Electricity export revenue	$	683,586
Electricity export escalation rate	%	2%

Table 4: Revenue generated on RD 26

Costs | Savings | Revenue

Initial costs			
Initial cost	100%	$	971,400
Total initial costs	**100%**	**$**	**971,400**
Annual costs and debt payments			
O&M costs (savings)		$	50
Debt payments - 15 yrs		$	74,658
Total annual costs		**$**	**74,708**
Annual savings and revenue			
Electricity export revenue		$	683,586
Total annual savings and revenue		**$**	**683,586**

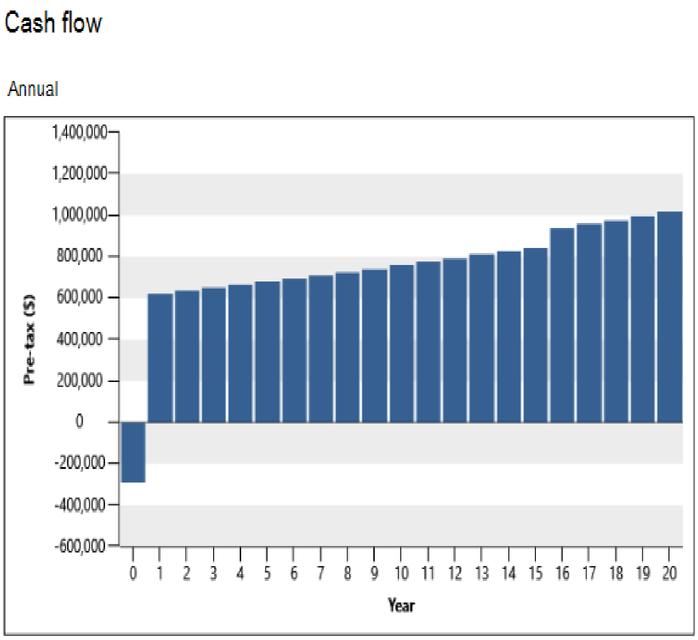


Figure 8: Cash Flow of RD 26

Conclusion

This study proposed a feasible case of RD 26 potential for grid connected small hydropower generation. By adopting the hydel energy total 2331 tons of carbon dioxide emission can be reduced in a year without affecting the electricity consumption.

It can be inferred from the study that even after deducting the initial cost and operation and maintenance cost not to mention the debt payment along with 6% tax; at 10 cents per kWh, the revenue generated is quite plausible evident in figure 3. From the revenue generation the community or even the government sponsor can replace and relinquish the system for hydropower generation.

The study also proved as a testimony that hydropower generation science is beyond a formula for estimation since, in real, the power generation is directly related to availability of firm flow throughout the year which in a long run is dependent on the residual flow. The complex chain of power capacity and electricity export rate also require meticulous flow adjustment factor and turbines. Since this study took a conservative approach i.e. minimum possible values were considered in order to be sure for hydropower generation since, for Sindh, run of river has been rarely proposed and an ambitious approach might have dwindled the possibility.

Summing up all, this study acts as testimony that RD 26 is potential candidate for hydropower generation that not only claims to illuminate thousand rural houses along with decrease in pollution but also ensures the revenue generation which in long term makes the system financially secure if only the operation and maintenance were to be carried out in a candid way.

Acknowledgments

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WATER SUPPLY MANAGEMENT FOR JAMSHORO CITY

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ABSTRACT

The case study is about Jamshoro city water management during the cut-off period of water for 15 days from Dec 25th to Jan 10th in Kalri Baghar canal. Kalri Baghar is an off taking canal from right bank of Kotri Barrage. During this cut off period Kotri Barrage authorities stop the flow of water in the canal for maintenance purposes and there is no supply of water to the city. Kalri Baghar canal is the only source of fresh water supply to Jamshoro city as the ground water is saline and not fit for potable use. So, during this cut off period most of the city relies on water supply through water tankers and the tanker mafia take advantage of this situation by increasing rates. Therefore, a water storage facility is needed which could fulfill the water demand of the city for these 15 days and could also be used throughout the year for constant supply. Different alternatives were assessed for the cut off period of K.B feeder and depending upon their feasibility, best alternative was selected. Construction of water storage lagoons was found out to be the most economic and efficient option. Findings revealed that lagoons are easy to build and operate. They have capacity to store sludge and a well-designed and properly managed lagoon have many other uses as well. The Lagoon designed have the capacity to supply water for 15 days to Jamshoro city. It can be used for throughout the year to meet the daily water demand of city. It can be used for irrigation and recreational purposes as well. The Cost Benefit analysis of Lagoon revealed that it's a viable solution against tanker water use.

Keywords

Indus river, Water management, Kotri barrage, K.B feeder canal, Lagoons

Introduction

The case study is about Jamshoro city water management during the cut-off period of 15 days from Dec 25th to Jan 10th, during this period there is no supply of water from K.B feeder to the city. Therefore, a water storage facility is needed which could fulfill the water demand of the city for these 15 days and could also be used throughout the year for constant supply.

Jamshoro city renowned for its educational institutions and societies has a serious water issue. Groundwater in Jamshoro is not drinkable, hence it solely depends on water supply from Kalri Baghar (K.B) feeder. Water supply to Kalri Baghar feeder is stopped every year from 25th Dec to 10th Jan for 15 days, due to maintenance purpose. People have to buy water through tankers for their daily needs, which is very expensive. Although the tanker mafia takes advantage of this situation, as Jamshoro city has no other conventional water supply alternative(s).

Worldwide most of the countries face this issue. They take some preventive measures to deal with water shortages. Reservoirs, water tanks, wastewater treatment plants, water pipe lines, CO2 cleaning and solar powered water purifiers are some of the vastly used alternatives to prevent water shortage. Some of which are considered for Jamshoro by considering the economical and geographical conditions of the city.

Construction of overhead tanks, construction of water reservoir, supply of water through water tankers and construction of water storage lagoons were some of the options considered for solving the water issue of Jamshoro city.

Currently during the cut off period people rely on water supply through water tankers which is highly uneconomical and most of the poor community cannot afford it. These different alternatives were assessed and depending upon the economic cost of the project and geographical condition of the city best possible solution was selected i.e. construction of water storage lagoons.

Methodology

Parameters Identified

Following parameters were identified and methods adopted for data collection

Water Supply

K.B feeder daily water supply data of 10 years was acquired. From the acquired data, the data of Dec and Jan was related to this case study. This data was used to plot supply-extraction graph which will be shown in later section.

Water Extracted

It was found that there are 12 to 13 colonies in Jamshoro city which extract water from the K.B feeder namely Jamshoro Pathak, Kotri, MUET university and some small colonies. MUET extracts 1MGD for the population of 1400 persons, keeping it in mind other extractions were determined using their population calculated from the average number of persons living per household.

Domestic Water Demand

135 liters per capita per day is the domestic water use. Total population was extrapolated for 50 years keeping a growth rate of 2.6% [1]. Considering the design factor for 25 years, population after 25 years i.e. 50342 persons was used and multiplied with the domestic water demand per capita per day for 15 days and a demand of 23MG (million gallons) was acquired.

Design

Trapezoidal lagoon was designed and its feasibility analysis was done in terms of cost benefit analysis.

Cost Benefit Analysis

It was done to validate long term benefits i.e. economic and social for the designed facility. It was calculated using Quantity Surveying methods of estimation and cost compared with the cost incurred in fulfilling demand without this facility.

Data Analysis

The type of data analysis adopted and tools used in this study are as follows.

Water Supply from K.B Feeder

Flow data analyzed in MS-EXCEL and only required data was used.

Water Extracted by the Colonies

The total volume extracted from a building is calculated by using the following formula:

Total water extracted =

No. of households x Persons per Household x (1MGD/1400).

Where:

1MGD is the volume extracted by MUET for 1400 persons.
Total present population was found to be 26500.
Total present volume extracted was found to be 19MGD.

PHATAK	2000*6*(1/1400) = 8.5 MGD
KOTRI PHATAK	1500*5*(1/1400) = 5.4 MGD
JAMSHORO COLONIES	800*7*(1/1400) = 4MGD

Table1. Volume Extracted by Colonies

Domestic Water Demand

Domestic Water demand is calculated by following method
Total Domestic Water demand =
Daily Domestic Demand* Extrapolated population of 25 years*15days
Where
Daily domestic demand= 135lpcd or 30gallons/day[2]
Extrapolated Population of 25 years=50342 persons
Total Domestic water demand was found to be 23MGD or 85740cu.m/day

Suitable Design

Lagoon was designed adopting the following method[3, 4]
The lagoons are designed as follows: -
Slope ratio =3:1
Depth = 2.5 m
Free board = 0.5 m
2 lagoons each has volume= 42870 m3

To Calculate Top Water Level (Twl) Length and Width

a) Calculate mid-depth surface area (m^2) = volume (m^3) / depth (m)
= 42870 m3 /2.5 m
= 17148 m^2
b) Work out some suitable dimensions for this mid-depth surface area.
Take 240 m X 72 m
c) Calculate the top water level (TWL) length and width:
TWL length (m) = mid-depth length (m) + (2 X (slope ratio x ½ water depth))
= 240 m + (3 x 2.5 m)
= 248 m
TWL width (m) = mid-depth width (m) + (2 X (slope ratio X ½ water depth))
= 40 m + (3 X 2.5 m)
= 79 m

To Calculate Base and Crest Dimensions

d) Calculate the base length and width:

Base length (m) = mid-depth length (m) - (2 X (slope ratio X ½ water depth))

= 240 m - (3 X 2.5 m)

= 233 m

Base width (m) = mid-depth width (m) - (2 X (slope ratio X ½ water depth))

= 79 m - (3 X 2.5 m)

= 64 m

f) Calculate the crest length and width:

Crest length (m) = TWL length + (2 X (slope ratio X freeboard depth (m))

= 247.5 m + (2 X (3 X 0. 5 m))

= 251 m

Crest width (m) = TWL width + (2 X slope ratio X freeboard depth (m))

= 79 m + (2 X (3 X 0.5 m)

= 82 m

2.2.4.3 Design of Inlet Pipe:

Discharge required to fill the lagoon in one day is calculated as follows: -

Discharge = Total Volume/day

=42870/ (24*60*60)

= 0.49 m3/sec = Q

The velocity of K.B feeder was found to be 1.19m/s

Q=Area*Velocity

Area= Q/Velocity

= 0.49/1.19 =0.142 m2

$\pi/4 * d2 = 0.412$

d2 = 0.52428

d = 0.7 m

Where d is the diameter of inlet pipe

Hence, for two lagoons two pipes of 0.7 m diameter are also required.

Cost-Benefit Analysis

The cost incurred in the design of lagoon as per Schedule of rates [5] is calculated as follows:

The volume required is distributed with water tankers then

A tanker supply 11 m3 of water for Rs 1200/ – Rs 1500/ varies with the distance covered by a tanker.

Then to supply 85740 m3 cost is calculated as follows: -

Cost= volume*price* no of years

=85740*(1200/11) *25 = Rs234, 000,000/ approx.

Cost per benefit ratio can be given as

=77,000,000/234,000,000

=0.33 which is less than 1

Results

The results calculated are as follow

1. Total present population was found out to be 26500.
2. Present volume extracted was found to be 19MGD.
3. Daily domestic demand= 135 lpcd or 30gallons/day
4. Extrapolated Population for 25 years=50342 persons
5. Total Domestic water demand was found to be 23MGD or 85740cu.m/day (for 25 years)

To meet this demand of 23MGD or 85740 m3/day water storage lagoon was designed as shown in figure 1.

1. Depth= 2.5m
2. Length of Crest(Lc)= 251m
3. Width of Crest(Wc)= 82m
4. Length of Base(Lb)= 233m
5. Width of Base(Wb)= 64m
6. Top water level Length(Lfsl)= 248m
7. Top water level Width(Wtwl)= 79m
8. Slope Ratio= 3:1
9. Free Board= 0.5m

Man-power		**Machine equipment.**	
Excavation	=2*42870*179.42 = Rs15,383,470/	Excavation	=2*42870*876 = Rs75,108,340/
Formation dressing and preparing subgrade with cement plaster 10mm thick (1:3)	a) Bed =2*2112*(66.18+115.51) =Rs767,459/ b) Side slopes =3440*(207.38+92.37) =Rs1,031,140/	Formation dressing and preparing subgrade with cement plaster 10mm thick (1:3)	a) Bed =2*2112*(66.18+115.51) =Rs767,459/ b) Side slopes =3440*(207.38+92.37) =Rs1,031,140/
Total cost	=Rs18, 000,000/ approx.	Total cost	=Rs77, 000,000/ approx.

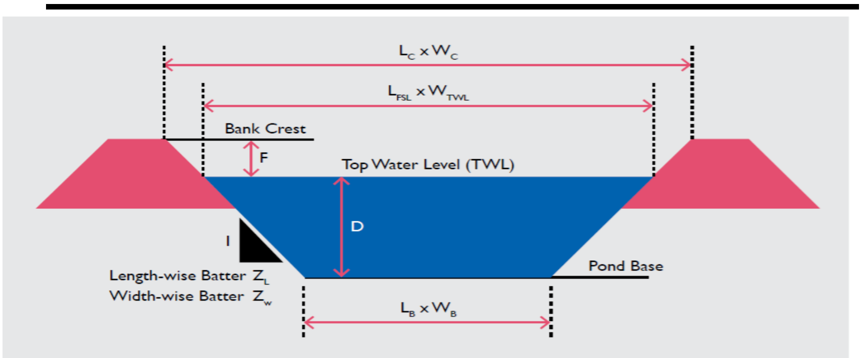

Figure 1. Water Storage Lagoons [3]

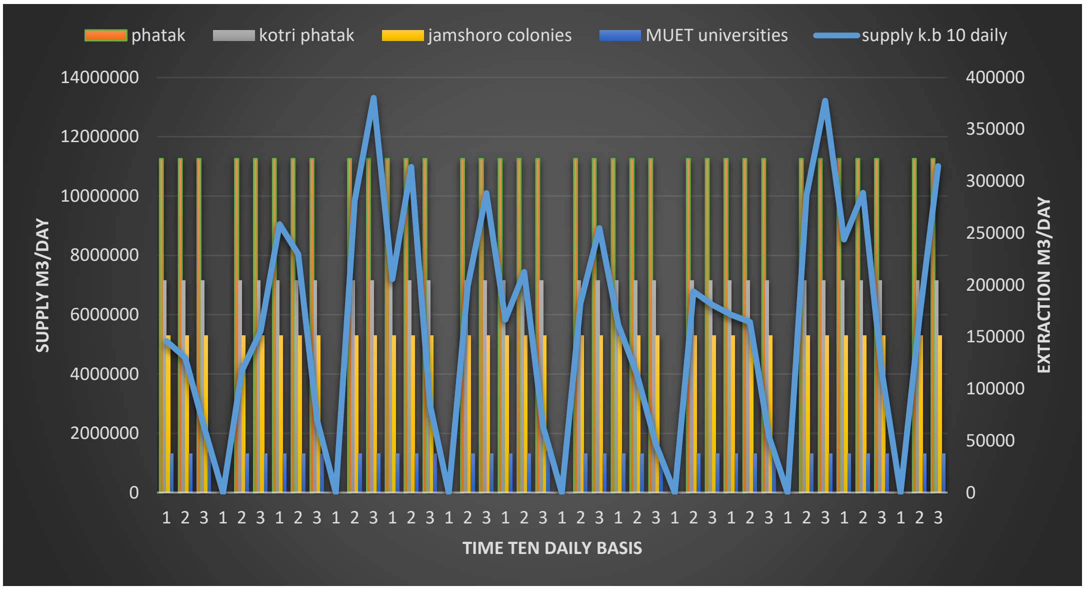

Figure 2. Relation between water supply and water extraction per day

Figure 2 shows that when there is no supply from K.B feeder, societies are unable to extract their required water. Population after 25 years would increase from 26500 to 50342 approximately.

Figure3. Relation between water extraction and water demand per day

Figure 3 shows that when societies don't extract water then they are unable to fulfill their domestic demand

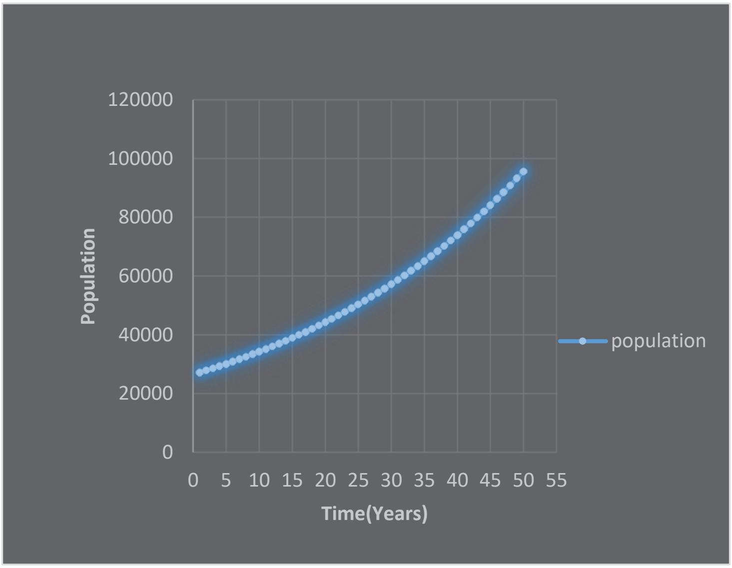

Figure4. Population of Jamshoro

After the cost benefit analysis, it was found that Lagoon is the most feasible option. The cost calculated in terms of water supply through tankers is approximately Rs 234,000,000 for 25 years while cost incurred in terms of lagoon construction is three times less i.e. Rs77, 000,000.

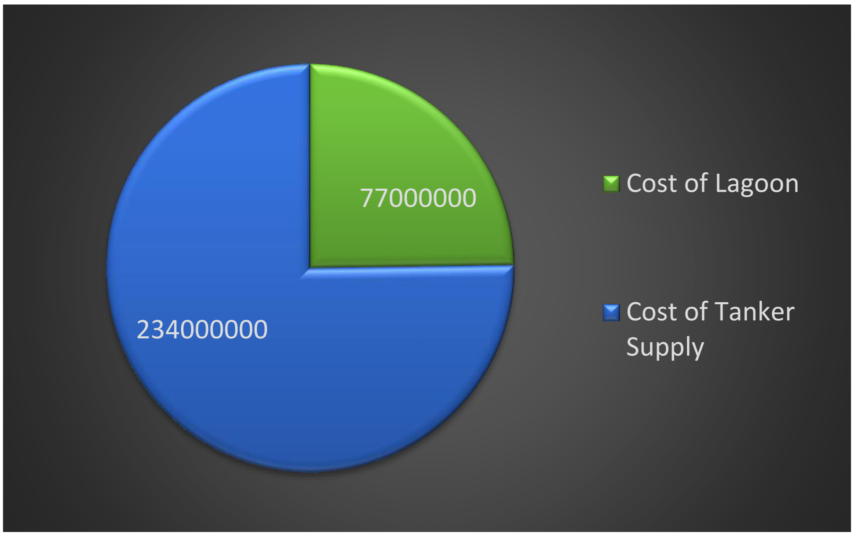

Figure 5. Cost of lagoon vs Tanker Supply

Conclusions

Construction of water storage lagoon was found out to be the most economic and efficient option. Findings revealed that lagoons are easy to build and operate. They have capacity to store sludge and a well-designed and properly managed lagoon have many other uses as well.

The Lagoon designed have the capacity to supply water for 15 days to Jamshoro city. It can be used throughout the year to meet the daily water demand of city. It can be used for irrigation and recreational purposes as well. The Cost Benefit analysis of Lagoon revealed that it's a viable solution against tanker water use

Limitations

The environmental aspects of the lagoon were not considered in this study which should be taken in account for further research.

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ANALYSIS OF WATER RESOURCES VULNERABILITY INDICATORS FOR

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ABSTRACT

Water is one of the basic needs for survival for living things, food and agricultural practices. The weather indicators play a significant role in evaluating and quantifying the water availability. In this research study, water resources vulnerability indicators for Jamshoro city, including temperature, precipitation, flow of Kalri Baghar canal, and population, were analyzed. Historic trend analysis (1990-2016) of temperature, precipitation, and flow of K.B feeder canal was carried out, followed by prediction of future temperature and precipitation trends (2017-2025) Furthermore, population of colonies extracting water from K.B feeder was extrapolated as per annual growth rate of 2.62. MS Excel was used as the tool for statistical analysis and future forecasting. The results showed the annual maximum temperature for the past trends (1990-2016) increasing up to +0.0013°C and predicted an increase of +0.00045°C in future trend (2016-2025). For annual minimum temperature, the results showed increase of +0.0026°C with an expected increase of +0.0009°C in future. On the other hand, the results of precipitation showed decrease in past trends -45.28% in Monsoon precipitation and decrease of -28.65% in future, while the Non-Monsoon precipitation show decrease in past trends -0.52% and decrease of -0.17% in future. Results of flow in K.B feeder showed an increase of 1135 Cusecs. With the growing population, increase in temperature and decrease in precipitation, there comes an increase in demand side of water availability. Therefore, it is advisable to manage the water demand and supply of water according to increasing population by integrated water resource management for sustainable use.

Keywords

Climate change, water resources, vulnerability, temperature, precipitation, flow, population, Jamshoro.

Introduction

Climate change is a global phenomenon demonstrated mainly through global warming. It has its adverse consequences on natural resources. It warms the atmosphere, alters the hydrological cycle and change the form, and intensity of
rainfall which ultimately has impacts on surface water availability. As Pakistan, has experienced the climate changes in the past years, therefore, its natural resources have also been affected including water as stated in "Express Tribune May 31, 2016, the Pakistan Council of Research in Water Resources (PCRWR)". Since water is the most essential resource for survival of all beings, it must be treated accordingly.

The irregular patterns of rainfall have been observed particularly in Sindh in recent decades. Extreme temperatures have also been noticed in most cities of Sindh. Rising temperatures are reducing the reliability and quality of water supplies. The above-mentioned variations in climate changes have resulted in surface water shortage.

On the other hand, the population is gradually increasing day by day with increase in water use. Since, as per recent studies

Pakistan is considered as water stressed nation. Ghulam Rasul, the director general of the Pakistan Meteorological Department (PMD), addressed in a commission that if the trend continues, the country will be in the list of water scarce countries by 2025 - A report "The time to focus on Infrastructure is now" published in Daily DAWN News Paper October 02, 2016.

To address the climate change in water sector, many international and national agencies are playing vital roles. World Wildlife Fund (WWF) is working to reduce the impacts of climate change in areas such as agriculture and land use, forests and water. WWF supports strong action for climate change adaptation and supports industries to adjust the changing climate and its cascading impacts. International Institute for Sustainable Development (IISD) is working in collaboration with Pakistan's Ministry of Climate Change on the project "Vulnerability of Pakistan's Water sector in the impacts of climate change" launched in July 2015. The project aims to improve decision-making capacity within government ministries, research institutes and the public in relation to water resources management in a changing climate. Different ways have also been adopted to address the climate related stresses. For example, after drought in Botswana (FAO, 2004) national government programs were launched like, to re-create employment opportunities, capacity building of local authorities. In Bangladesh (OECD 2003; Pouliotte,2006) certain strategies were adapted like consideration of climate change in national water management plan, building of flow regulators in coastal embankments, use of alternative crops and low technology water filters.

To identify the vulnerability of Jamshoro city with respect to water resources indicators we have carried out an annually, monthly and seasonal trend analysis of temperature and precipitation of Jamshoro City. Further, we have predicted the trends of precipitation and temperature of Jamshoro city. The flow of K.B Feeder have also been analyzed. The population of colonies extracting water from Jamshoro city have been extrapolated at the annual growth rate of 2.62.

The core objectives of this study were to analyze the past trends (1990-2016) of temperature and precipitation of Jamshoro city; the second goal was to forecast the future trends (2017-2025) of temperature and precipitation of Jamshoro city, the third aim was to analyze the trend of flow of Kalri Baghar (K.B) Feeder Canal, and the fourth aim was to extrapolate the population of colonies of Jamshoro city extracting water from K.B Feeder.

Materials And Methods

The Study Area

Jamshoro is a capital city of Jamshoro District, Sindh, Pakistan.

Jamshoro is situated at 25.43° North latitude, 68.28° East longitude and 13 meters elevation above the sea level. Jamshoro is a small community in Pakistan, having about 0 inhabitants. Jamshoro, is situated on the right bank of Indus River at south-west position of Province of Sindh sloping from direction North-east to south-west and is about 18 kilometers far from Hyderabad and at a distance of 150 kilometers from Karachi. Jamshoro, the site of largest University residential campus in the country. Jamshoro is virtually the gate-way to the Indus Valley, now world famous for its civilization and rich cultural heritage. The total geographical area of the district is 11,517 square kilometers. It is about 220 kilometers from north to south and about 100 kilometers wide from east to west. A 2 to 6 kilometres wide belt of the west bank of River Indus is cultivated and irrigated and the remaining land of the district is either hilly or cultivated. Agriculture is the main source of income. In summer, the northern part (Sehwan) is hotter than that of other parts of the district and normally cool in winter.

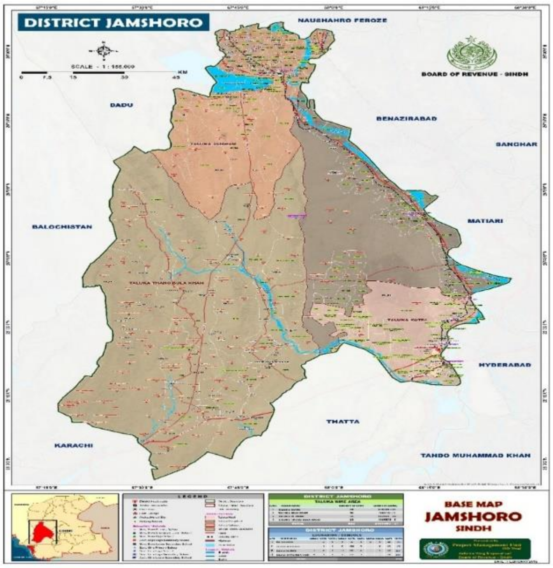

Figure:1:- Study Area Map.

Source: http://map.sindhzameen.gos.pk/SindhMaps.aspx

Parameters Identified

Meteorological

The past trend for these indicators has been analyzed and the future trends are forecasted. Extreme values for above mentioned parameters are also identified.

Hydrological

Past trend of annual flow of K.B Feeder (1990-1998 & 2008-2013) is analyzed.

Demographic

Based on 2015 population data for Colonies of Jamshoro city, the future population is extrapolated until the year 2025.

Method Adopted For Data Collection

Meteorological data (temperature and precipitation) from 1990 to 2015 is acquired from the National Oceanic and Atmospheric Administration (NOAA).

Hydrological data, flow of K.B Feeder from 1990 to 1998 and from 2008 to 2013 is collected from the officials of Institute of Water Resources Engineering & Management department, MUET, Jamshoro.

The demographic data, population (2015) of colonies of Jamshoro city, which extract water from K.B Feeder is drawn from the report submitted by previous batch students [2].

Type of data analysis adopted and tools used

Ms Excel, 2016

- The past trends, from 1990-2016, of temperature (annual and monthly) and precipitation (annual, monthly, non-monsoon and monsoon) have been analyzed.
- The future trends, from 2016-2025, of temperature (annual and monthly) and precipitation (annual, monthly, non-monsoon and monsoon) have been analyzed.

- The past trend analysis, from 1990-2016, of flow of K.B Feeder (annual) have been carried out.
- The population of Jamshoro city colonies, extracting water from K.B Feeder, is extrapolated as per annual growth rate of 2.62.

Ms Excel, 2016

- To validate the data of above mentioned water stress indicators, time series test (Mann-Kendall trend test).

Results

Graphs And Tables

- The past trends, from 1990-2016, of temperature (annual and monthly) and precipitation (annual, monthly, non-monsoon and monsoon) have been analyzed.
- The future trends, from 2016-2025, of temperature (annual and monthly) and precipitation (annual, monthly, non-monsoon and monsoon) have been analyzed.

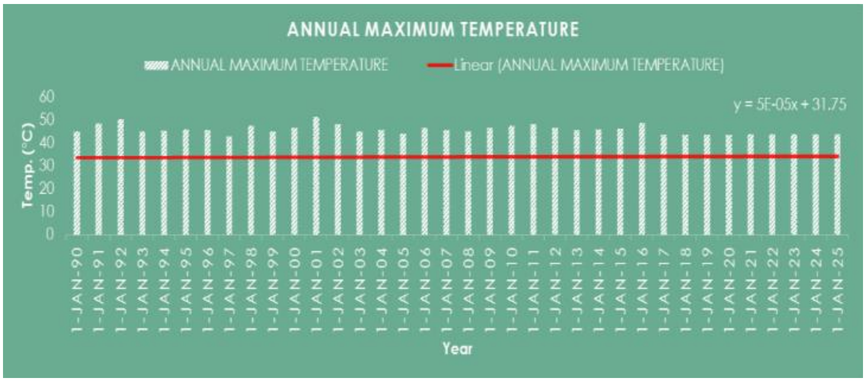

Figure 2: Representation of Annual Maximum temperature

This graph shows that the annual maximum temperature for the past trends (1990-2016) is likely to increase (+0.0013°C) and predicts an increase (+0.00045°C) in future trend (2016-2025). The p-value of annual maximum temperature is 0.002 and Sen's slope is 3.287E-5.

Annual Minimum Temperature

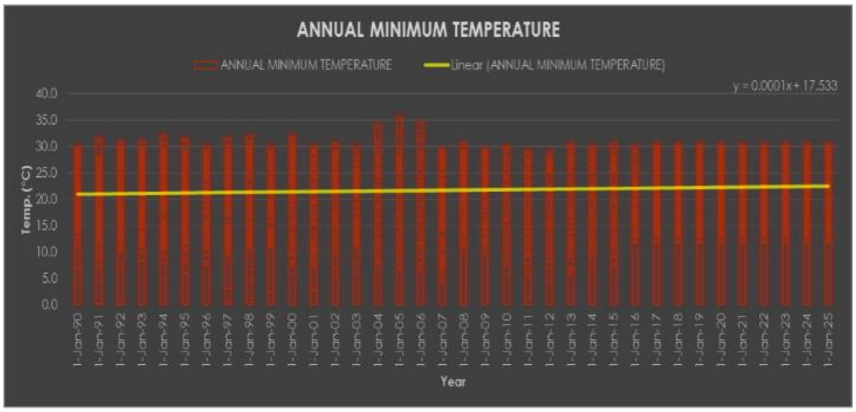

Figure 3: Representation of Annual Minimum Temperature

This graph shows the increase (+0.0026°C) in annual minimum temperature for the past trends (1990-2016) and expected to increase (+0.0009°C) in future trend (2016-2025). The p-value of annual minimum temperature is <0.0001 and Sen's slope is 1.080E-4.

Table:1: - Values of past (1990-2016) and future (2017-2025) trends of Temperature

Temperature °C	From 1990-2016 (difference)	From 2016-2025 (expected difference)
Annual Maximum	+0.0013°C	+0.00045°C
Annual Minimum	+0.0026°C	+0.0009°C

Monsoon Precipitation

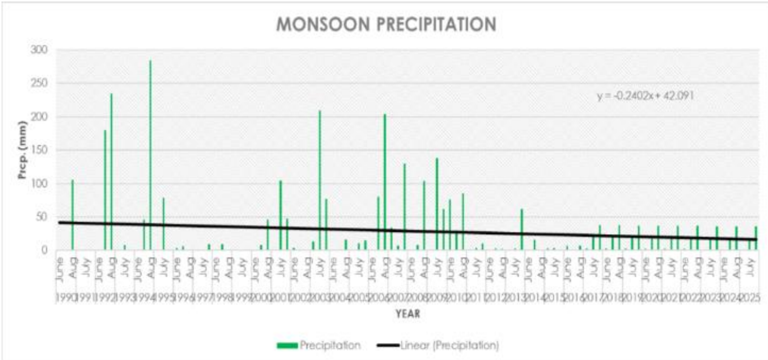

Figure 4: Representation of Monsson Precipitation

This graph shows the past trend of decreasing (-45.28%) Monson precipitation from 1990-2015 and it also shows the future prediction of decreasing (28.65%) Monson precipitation for the years 2016-2025. The p-value is 0.029 and the Sen's slope is 0.026.

Non-Monsoon Precipitation

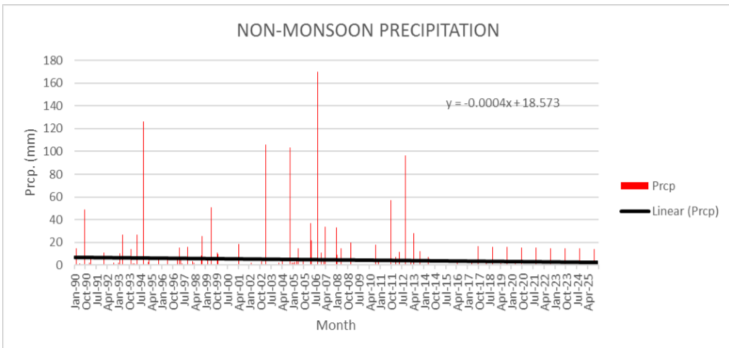

Figure 5: Representation of Non-Monsoon Precipitation

This graph shows the past trend of decreasing (-0.52%) Non-Monson precipitation from 1990-2015 and it also shows the future prediction of decreasing (-0.17%) precipitation for the years 2016-2025. The p-value of the above graph is 0.009 and the Sen's Slop is 0.

Table:2: - Values of past (1990-2016) and future (2017-2025) trends of precipitation.

Table 2: Values of past (1990-2016) and future (2017-2025) trends of precipitation

Precipitation (mm)	From 1990-2016 (%change)	From 2016-2025 (expected %change)
Monsoon	-45.28	-28.65
Non-Monsoon	-0.52	-0.17

KB Feeder Flow

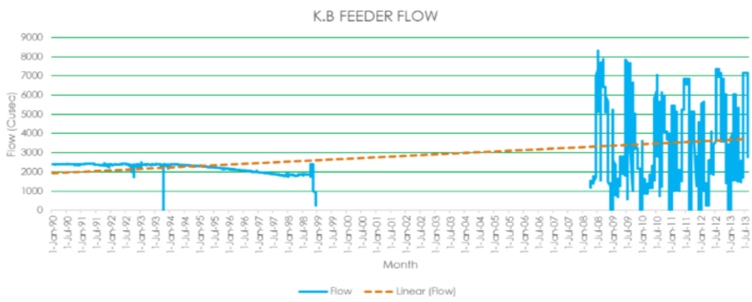

Figure 6: Representation of K.B Feeder Flow

In this graph the results of flow in K.B feeder showed an increase of 1135 Cusecs and the statistical values of this are P-value (<0.0001) & Sen's slope is (-0.063).

Population of Colonies of Jamshoro City

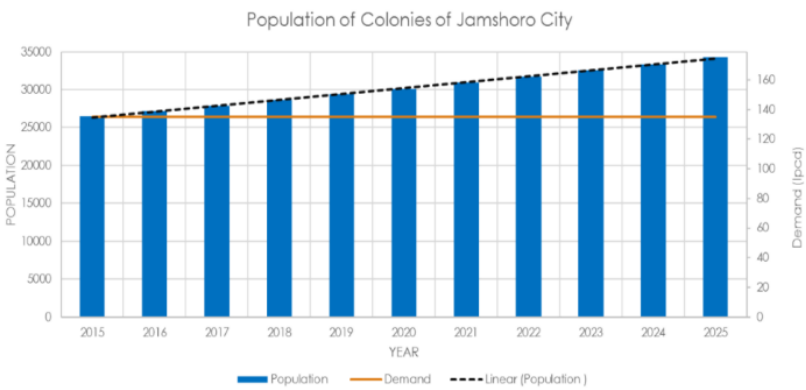

Figure 7: Representation of Population of Colonies of Jamshoro City

Statistical Test Results/Tables

(Mann-Kendall trend test / Two-tailed tests):

Table:1: - Temperature (°C).

Temperature	**p-value**	**Sen's Slope**
Maximum temperature	0.002	3.287E-5
Minimum temperature	< 0.0001	1.080E-4

Table:2: - Precipitation (mm (%)

Monsoon	0.029	0.026
Non-Monsoon	0.009	0

Table:3: - K.B Feeder Flow (Cusec)

Flow	**p-value**	**Sen's Slope**
Annual Flow	< 0.0001	-0.063

Table:4: - Population

Population	p-value	Sen's Slope
Jamshoro's thirteen colonies population (2015-2016)	< 0.0001	774.104

Discussion & Conclusion

The past trends of water stress indicators, from 1990 to 2016, have been analyzed and future trends, from 2016 to 2025, have been predicted. The indicators include temperature, precipitation, flow of K.B Feeder and population of colonies of jamshoro city, extracting water from K.B Feeder. The analysis shows that the increase in annual maximum temperature from the year 1990-2016 is 0.0013°C and it is expected to rise up to 0.00045°C till 2025. Whereas, the minimum annual temperature for the past trend has slightly increased up to 0.0026°C and estimated to further rise 0.0009°C. However, the monthly trends are found to be different from annual. The monthly maximum temperature has inclined to 0.97°C from 1990-2016 and projected to increase up to 0.33°C. While the monthly minimum temperature has decreased 0.48°C during 1990-2016 and expected to further decrease 0.17°C till 2025. The analysis of precipitation shows that the it has decreased 40.63% annually and 26.56% monthly during the years 1990-2016. While it is forecasted to further decline to 23.69% and 34.37% annually and monthly respectively. The previous trends of non-monsoon (Sept-May) show the decrease in rainfall up to 0.52% and it is predicted to further decline to 0.17% till 2025. Similarly, monsoon rainfall has also decreased to 45.28% and will also decrease 28.65% by the year 2025. The analysis of flow of K.B Feeder demonstrates an increasing trend from 1990 to 2013. As, from 1999 to 2007 the flow data is not available therefore it cannot be forecasted. The population of colonies extracting water from K.B Feeder was 26500 in the year 2015 and as per annual growth rate of Hyderabad i.e. 2.62 (Bureau, 1998) it is expected to rise further to 34255 by 2025.

All above it can be concluded that Jamshoro city is vulnerable with respect to Temperature as it has increased slightly and is expected to rise till 2025. The city is also vulnerable in terms of Precipitation as it has decreased significantly and is likely to decline further till 2025 in Mon-soon season, contributing a notable proportion in decreasing the annual rainfall. Jamshoro city colonies extracting water from K.B Feeder are not vulnerable to the water because the flow in recent past years has increased in the K.B Feeder. Population of colonies of Jamshoro city is also expected to increase as per annual growth rate of 2.62.

Recommendations

- Use models like Global Climatic Model (GCM) or Regional Climatic Model (RCM) to achieve better results.
- Do the study at larger scale, provincial or national.

Limitations

- Data of temperature and precipitation before 1990 was not available, therefore we analyzed the past trends for 27 years.
- The tool used in this study is limited to MS-Excel 2016.
- The flow data of K.B Feeder is missing between the years 1998 and 2008.

Acknowledgments

- Our thanks to Mr. Shankar Lal, Mr. Waqas and Mr. Tahir Ali Shaikh for corresponding and helping us in this work.

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A MULTI INDEX PERSPECTIVE FOR DROUGHT CHARACTERIZATION IN SINDH PAKISTAN

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ABSTRACT

Sindh province is located in the subtropical zone of Pakistan and experience frequent droughts. The recurring droughts pose significant risk to the water resources of the area and their dependent ecosystems. The scarce network of met stations is not sufficient to provide reliable spatial and temporal information of drought severity across the study area. The characteristics of agriculture and meteorological droughts are studied from 1980-2016. Standardized Precipitation Index (SPI) and Standardized Soil Moisture Index (SSI) are used as indicators to study meteorological and agriculture droughts respectively. A meteorological drought is defined by deficit in precipitation and agriculture drought is defined by deficit in soil moisture content. A combination of SPI and SSI is studied using a Multivariate Standardized Drought Index (MSDI). The index is based on the combination of the joint probability of SPI and SSI. The characteristics of historical droughts, their onset, persistence and termination are studied using MSDI. The results obtained from MSDI are compared with the SPI and SSI. The results indicate that MSDI gives reasonable information for overall drought characterization and is a reliable indicator for drought analysis in data scarce regions. It has been observed that the drought staring from 1998 till 2003 is the most severe drought in the past 36 years. The precipitation and soil moisture data used in the study is taken from the Modern Era Retrospective Analysis for Research and Application (MERRA) product of Goddard Earth Observing System NASA. The drought information using MERRA data used in this study is available from the Global Integrated Drought Monitoring and Prediction Systems (GIDMaPS), University of California, Irvine.

Keywords

Drought, Soil Moisture, Agriculture, Meteorological droughts, SPI, SSI, Multi variable Index.

Introduction

Drought is a slow onset event or creeping phenomena and results in devastating social and ecological effects. The spatial extent of droughts has increased to over 50% worldwide during the last century [18]. In Asia alone droughts have caused a loss of $29.5 billion during the period of 1970-2008 [3, 10, 14]. Thus, characterizing drought with accurate prediction and monitoring is of critical importance in making water allocation decisions. Since drought is a slow creeping process no single definition of drought completely encompasses the drought phenomena for various uses of water resources. Four definitions of drought are meteorological, hydrological, agricultural, and socioeconomic [21, 22]. A meteorological drought is defined by deficit in precipitation and agriculture drought is defined by deficit in soil moisture content. Hydrological drought is characterized by low stream flow, groundwater and reservoir levels than the average conditions. A socio economic drought is defined by unevenness of demand and supply ratio [8, 9]. Drought monitoring is done with different indices developed worldwide. The most commonly used indicator is Standard Precipitation Index (SPI) [11]. SPI has been recommended by World Meteorological Organization (WMO) as an effective tool for early detection and monitoring of meteorological droughts [6]. The theory of SPI can be used to derive Standardized Soil Moisture Index: a measure of agriculture drought [4].

Sindh is located in southeast of Pakistan and experience frequent droughts. The Tharparkar district of Sindh is most affected with droughts. It is third consecutive year of drought in Tharparkar. The ongoing drought in the area has caused several deaths. The water borne and viral diseases have killed thousands of small animals. The agriculture of the area is also affected causing food security in the area.

The accurate monitoring and prediction of drought depends on different climate variables and a single index cannot reliably detect the onset, persistence and termination of drought. A multi variable index has been proposed by [4, 5] that combines the agriculture and meteorological drought and give a composite probability for the overall drought characterization. The index named as Multivariable Standardized Index (MSDI) utilizes the SPI and SSI for meteorological and agriculture droughts with drought onset dominant by SPI and drought persistence based on SSI [4].

The objective of the paper is to study the agriculture and meterological droughts in Sindh from 1980-2016 using MSDI. The index uses the information of soil moisture and precipitation for agriculture and meteorological droughts. The soil moisture and precipitation data of National Aeronautics and Space Administration's (NASA) Modern Era Retrospective analysis for Research and Applications [15] available at $2/3° \times 1/2°$ from 1980 onward is used in the study

Study Area and Data Sources

Sindh is located in tropical to subtropical region. The spatial extent of Sindh is 579 km from North to South, 281 Km from East and West. Sindh borders with Punjab province in North, Thar Desert in East, Kirthar mountain ranges in West and Arabian Sea in South. The total area is approximately 140,915 square kilometers. There are 29 districts in Sindh as shown in Fig. 1

The population of Sindh is approximately 56 million people including the metropolitan Karachi. The important crops of Sindh are sugar cane, rice, wheat, dates and mangoes. The main sources of agriculture water are canal irrigation system and tube wells.

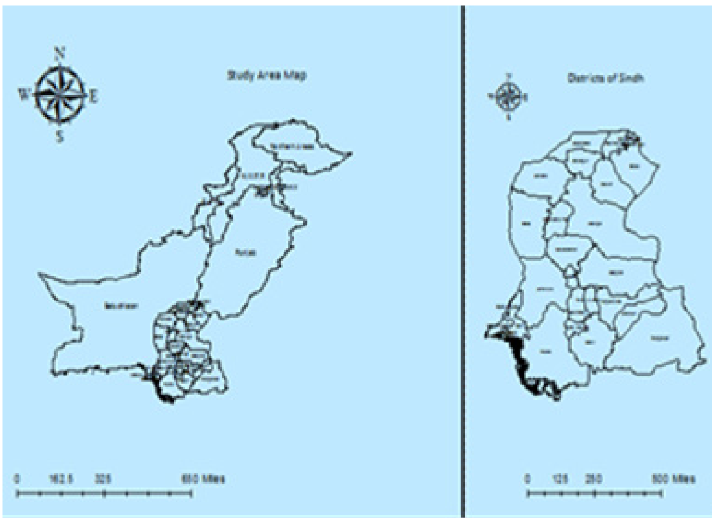


Figure.1 Districts of Sindh

The MERRA-LAND data of NASA is available from 1980 onwards. Fig 2 shows the grid points for NASA data and the location of Pakistan Meteorological Department (PMD) stations. The monthly precipitation data available from NASA is coorelated with the available monthly data of Pakistan Meteorological Department (PMD).

A total of 5 stations of PMD are used which have data of more than 25 years from 1980. The available data of Karachi and Hyderabad stations is from 1980-2010 while Badin, Chor and Mohenjadaro station is from 1980-2006. The correlation results are shown in Fig.3. The scatter plot shows that there is a good agreement between lower values of data for all stations.

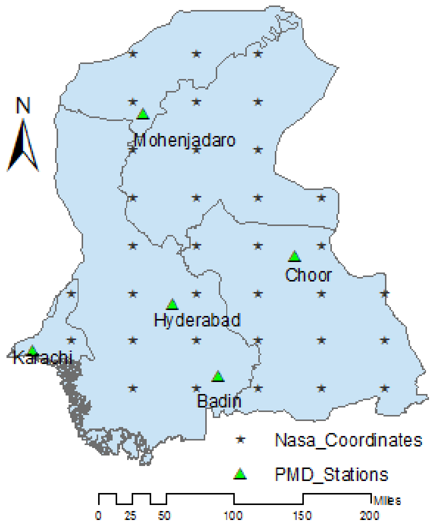
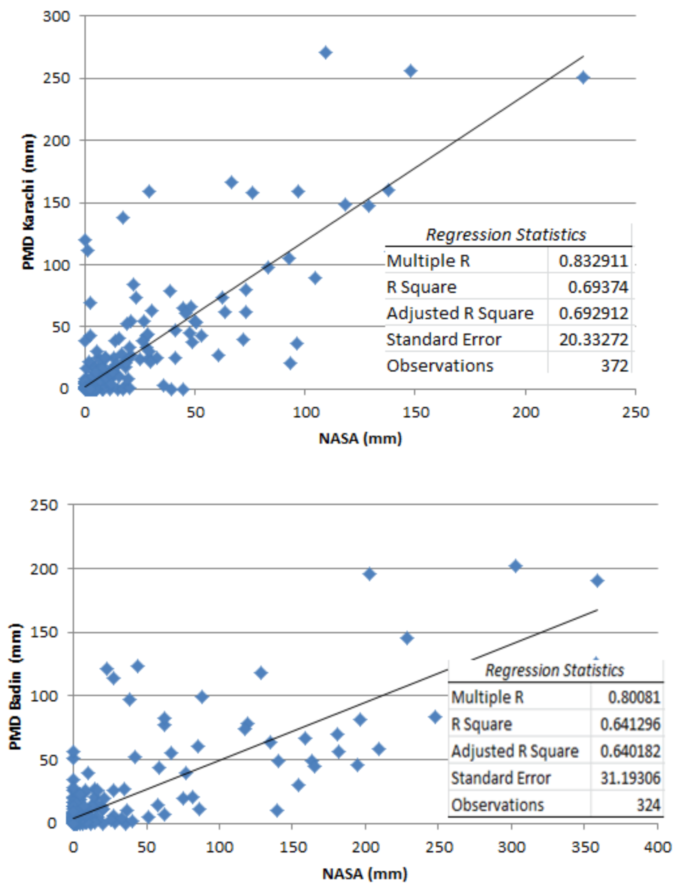
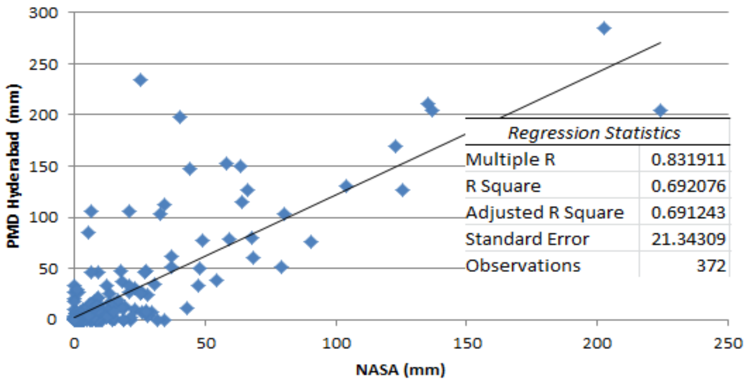
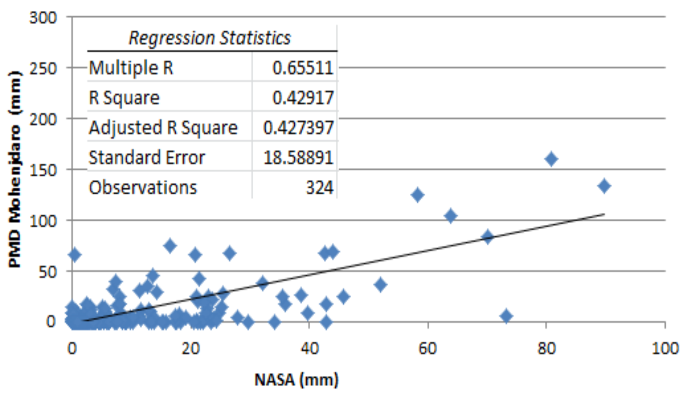
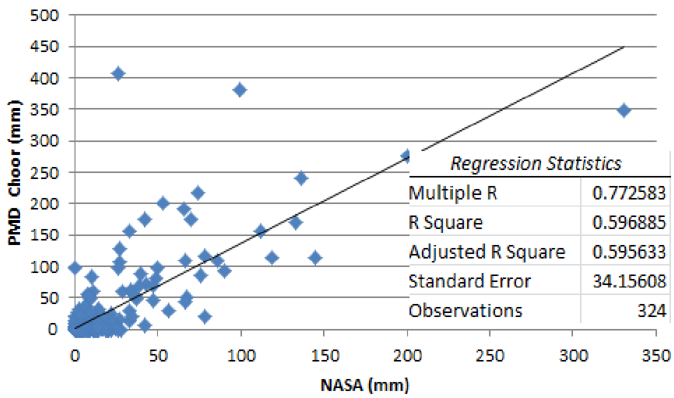


Figure.2 NASA and PMD coordinates









Methodology

Monthly mean rainfall and soil moisture data is used to calculated SPI and SSI at each of the grid points. The procedure to calculate SPI and SSI is same. SPI is developed by [11] and it takes into account the precipitation data at different grid points. A gamma distribution is found to fit the precipitation time series [7]. The probability density function of gamma distribution is given by

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \qquad \text{for } x>0$$

Where

α> 0 α is a shape parameter

β >0 β is a scale parameter

x>0 x is precipitation

Ţ(α) is a gamma function given as

$$\hat{\alpha} = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\hat{\beta} = \frac{\bar{x}}{\hat{\alpha}}$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

n= number of observations

The cummulative probability for precipitation is given by

$$H(x) = q + (1 - q)G(x)$$

The probability of zero G(x) is given by q in above equation [11]. The values of this cumulative probability are changed to a standard random variable z which gives the value of SPI index with a mean of zero and variance of 1. The similar procedure is for the calculation of SSI with soil moisture data.

The calculation of MSDI is based on extending the SPI and SSI into a bivariate model that gives the joint probability of the soil moisture and precipitation deficit for overall drought characterization [4]. Consider precipitation and soil moisture as random variable X and Y at different time scales (e.g. 3 or 6 months) the joint distribution of X and Y can be written as

$$P(X \le x, Y \le y) = p \qquad (1)$$

In above equation the joint probability of precipitation and soil moisture is given by p. According to [4] MSDI can be defined based on joint probability p as

$$MSDI = \phi^{-1}(p) \qquad (2)$$

ϕ in above equation is standard normal distribution.

There are two approaches to find the joint probability in equation.1. These two approaches are parametric and nonparametric. The parametric approach discussed by [4] uses the concept of copulas [13] to find the joint distribution. Consider equation1 written in the following form

$$P(X \le x, Y \le y) = C[F(X), G(Y)] = p \qquad (3)$$

where X and Y are random variables representing precipitation and soil moisture, C is the copula and F(X), G(Y) are the marginal cumulative distribution functions [4]. The copula C gives the joint probability of X and Y in the form of their marginal distributions [4]. There are a lot of copulas that have been developed e.g. Frank, Gumbel and Clayton copulas. The Frank copula is given as [16]

$$C(u, v) = -\frac{1}{\theta} \ln\left[1 + \frac{(e^{-\theta u} - 1)(e^{-\theta v} - 1)}{e^{-\theta} - 1}\right]$$

u,v are the marginal cumulative probabilities of precipitation and soil moisture and ɵ is the parameter [4]. ɵ can be estimated from Kendall's rank correlation and given by [1]

$$\tau = 1 + 4[D(\theta) - 1]/\theta$$

$$D(\theta) = \frac{1}{\theta}\int_0^{\theta} \frac{t}{\exp(t) - 1}\,dt$$

t is the integration variable in above equation. For more information on copula functions see [12].
MSDI can be defined for cumulative joint probability from equation (3) as
MSDI=ϕ-1(p)
where ϕ is standard normal distribution.
The nonparametric approach does not involve the parameter estimation. A bivariate form of joint probability is discussed by [5] that use Gringorten plotting position formula [18]

$$P(x_k, y_k) = \frac{m_k - 0.44}{n + 0.12}$$

In equation (5) n is the number of observations and mk is the number of occurrences of pair (xi,yi) for xi ≤xk and yi≤yk (1≤i≤n) (5). The joint probability obtained from equation (5) is used in equation 1 to obtain the MSDI. The positive values of the indices represent wet conditions and the negative values represent dry conditions [4].

Results

The SPI, SSI and MSDI are calculated on 3 and 6 months' time scales on all the grid points. The indices values are converted into D scale for better representation. Starting from D0 to D4: D0 (abnormally dry), D1 (moderate drought), D2 (severe drought), D3 (extreme drought), and D4 (exceptional drought) [17]. The above drought categories denote the following ranges in SPI, SSI and MSDI: −0.5 to −0.7 (D0), −0.8 to −1.2 (D1), −1.3 to −1.5 (D2), −1.6 to −1.9 (D3), and −2.0 or less (D4)

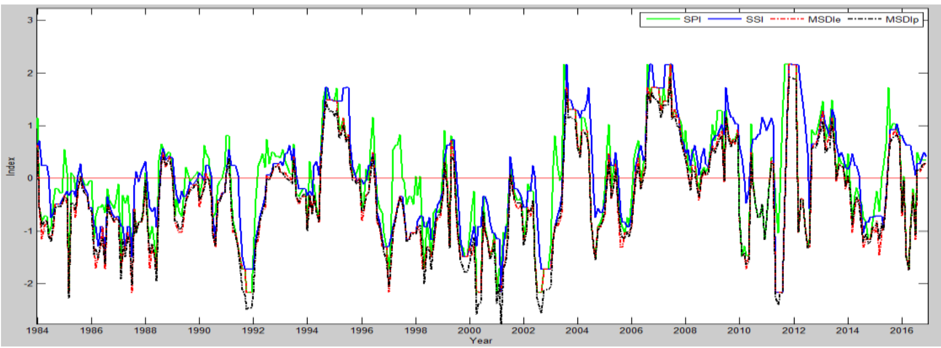


Fig.4: 6-Month SPI, SSI, MSDIe, MSDIp over Sindh from 1984-2016

Fig. 5 shows the separate results of the SPI, SSI MSDIe and MSDIp with time scale of 6-month. A total of 140 drought events are found under SPI, 129 with SSI, 177 with MSDIe and 190 with MSDIp ranging from D0 to D4 over the period of 1980-2016. The information for period of drought from February 1986 to July 1988 is presented in Table-1. The table shows that MSDI gives the drought onset and termination based on the combined effect of SPI and SSI. It can be seen that MSDI gives higher negative value for drought onset which makes it a better indicator for drought monitoring.

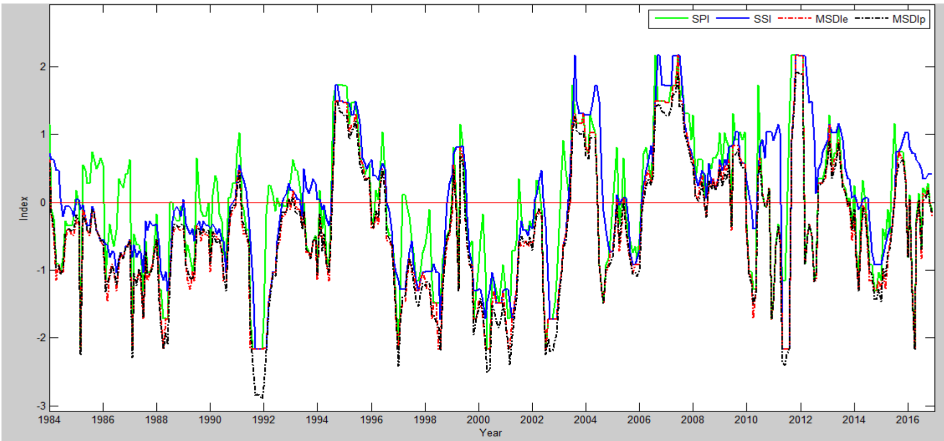


Fig.6 Temporal variation of 3-Month SPI, SSI, MSDIe, MSDIp over Tharparkar district 1984-2016

The period of 3-Month drought from 1984 to 2016 in Tharparkar district is shown in Fig-6 and 6-Month drought over Sanghar district is shown in Fig 7. The Tharparkar district remains in a constant grip of droughts as shown in Fig 6.

As shown in the Fig 4, 6 and 7 the drought onset is mostly dominant with SPI as compared to SSI with exceptions as well in which SSI shows the dry period while SPI shows a wet spell. It could be explained with a fact that a large amount of rainfall can occur for a very short time in a month which may end the meteorological drought but the agriculture drought remains during the month.

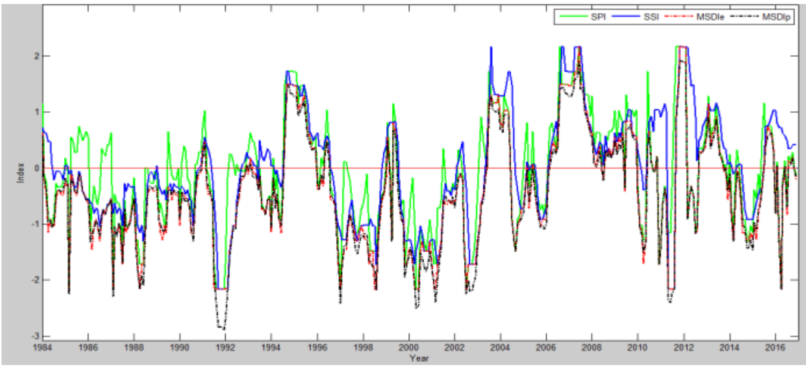


Fig. 7 6-Month SPI,SSI,MSDIe and MSDI p over Sanghar District 1984-2006

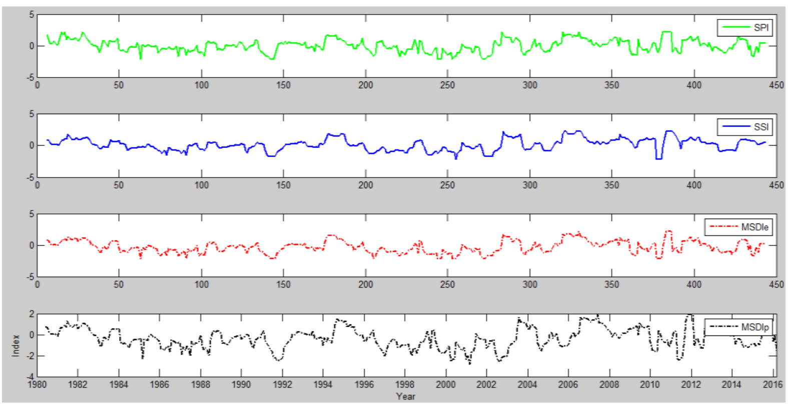


Fig.5 6-Month SPI, SSI, MSDIe, MSDIp over Sindh from 1980-2016

Year	Month	SPI	SSI	MSDIe	MSDIp
1986	February	-1.14	-0.91	-1.29	-1.45
1986	March	-0.72	-0.91	-1.71	-1.34
1986	April	-0.55	-1.29	-1.47	-1.51
1986	May	-0.55	-0.91	-1.29	-1.20
1986	June	-0.49	-0.93	-0.93	-1.13
1986	July	-0.65	-1.48	-1.73	-1.62
1986	August	-0.20	-0.34	-0.49	-0.49
1986	September	-0.42	-0.49	-0.57	-0.63
1986	October	-0.49	-0.65	-0.74	-0.73
1986	November	-0.57	-0.74	-0.83	-0.81
1986	December	-0.42	-0.74	-0.74	-0.77
1987	January	-0.10	-0.72	-0.81	-0.79
1987	February	-1.71	-0.91	-1.71	-1.91
1987	March	-0.32	-0.91	-1.47	-1.16
1987	April	-0.47	-1.29	-1.29	-1.48
1987	May	-0.32	-0.91	-1.02	-1.11
1987	June	-0.65	-0.93	-1.16	-1.20
1987	July	-1.48	-1.48	-2.17	-2.03
1987	August	-0.57	-0.14	-0.57	-0.64
1987	September	-1.04	0.14	-1.04	-1.04
1987	October	-0.83	-0.07	-0.83	-0.83
1987	November	-0.83	0.14	-0.83	-0.83
1987	December	-0.65	0.20	-0.74	-0.65
1988	January	0.10	0.32	-0.10	-0.04
1988	February	-0.91	-0.25	-1.02	-1.01
1988	March	-1.14	-0.55	-1.71	-1.43
1988	April	-0.91	-0.63	-1.29	-1.25
1988	May	-1.29	-0.55	-1.47	-1.50
1988	June	-1.73	-0.93	-1.73	-1.97
1988	July	0.34	-0.34	-0.34	-0.40
1988	August	0.65	0.42	0.27	0.31

Year	Month	SPI	SSI	MSDIe	MSDIp
1997	August	-0.07	-0.65	-0.74	-0.70
1997	September	-0.49	-1.16	-1.16	-1.20
1997	October	-0.34	-1.16	-1.16	-1.17
1997	November	-0.34	-1.04	-1.04	-1.04
1997	December	-0.49	-1.04	-1.04	-1.06
1998	January	0.03	-1.02	-1.02	-1.05
1998	February	-0.32	-0.81	-0.91	-0.94
1998	March	0.03	-0.72	-1.02	-0.89
1998	April	-1.14	-0.72	-1.71	-1.47
1998	May	-1.71	-0.91	-1.71	-2.00
1998	June	-0.83	-0.93	-1.31	-1.29
1998	July	-1.16	-0.74	-1.31	-1.38
1998	August	-1.48	-1.16	-1.48	-1.74
1998	September	-0.65	-1.16	-1.31	-1.23
1998	October	-0.57	-0.65	-0.83	-0.76
1998	November	-0.65	-0.49	-0.74	-0.72
1998	December	-0.57	-0.42	-0.74	-0.64
1999	January	0.17	-0.25	-0.32	-0.34
1999	February	0.91	0.39	0.32	0.30
1999	March	-0.03	0.63	-0.10	-0.18
1999	April	-1.29	0.63	-1.29	-1.31
1999	May	0.81	0.72	0.72	0.43
1999	June	0.57	0.74	0.34	0.35
1999	July	-0.57	0.14	-0.74	-0.64
1999	August	-1.04	-0.34	-1.16	-1.09
1999	September	-1.31	-1.16	-1.48	-1.55
1999	October	-1.31	-1.48	-1.48	-1.70
1999	November	-1.48	-1.48	-1.48	-1.78
1999	December	-1.48	-1.48	-1.48	-1.79
2000	January	-1.02	-1.29	-1.29	-1.58
2000	February	-0.63	-1.14	-1.47	-1.32
2000	March	-0.25	-0.91	-1.29	-1.13
2000	April	-2.16	-1.29	-2.16	-2.57
2000	May	-2.16	-0.91	-2.16	-2.39
2000	June	-2.17	-0.93	-2.17	-2.36

2000	July	-0.34	-0.34	-0.74	-0.63
2000	August	-0.93	-0.34	-1.04	-0.99
2000	September	-1.16	-0.49	-1.16	-1.20
2000	October	-1.48	-0.83	-1.48	-1.53
2000	November	-1.31	-1.04	-1.31	-1.42
2000	December	-1.04	-1.04	-1.16	-1.23
2001	January	-2.16	-1.14	-2.16	-2.37
2001	February	-1.71	-1.14	-2.16	-2.01
2001	March	-1.71	-2.16	-2.16	-2.86
2001	April	-1.02	-1.29	-1.71	-1.73
2001	May	-1.14	-0.91	-1.47	-1.55
2001	June	-0.57	-0.93	-1.04	-1.16
2001	July	0.27	0.42	0.07	0.08
2001	August	-0.14	0.07	-0.20	-0.25
2001	September	-0.27	-0.20	-0.42	-0.40
2001	October	-0.42	-0.20	-0.57	-0.47
2001	November	-0.42	-0.27	-0.57	-0.48
2001	December	-0.34	-0.34	-0.49	-0.46
2002	January	-1.14	-0.55	-1.14	-1.27
2002	February	-0.81	-0.55	-1.02	-1.03
2002	March	-0.10	-0.25	-0.55	-0.59
2002	April	-0.25	-0.25	-0.72	-0.63
2002	May	-0.25	0.25	-0.47	-0.41
2002	June	-1.48	0.07	-1.48	-1.52
2002	July	-2.17	-0.74	-2.17	-2.28
2002	August	-2.17	-1.48	-2.17	-2.48
2002	September	-2.17	-1.73	-2.17	-2.55
2002	October	-1.73	-1.73	-1.73	-2.14
2002	November	-1.73	-1.73	-1.73	-2.11
2002	December	-1.73	-1.73	-1.73	-2.12
2003	January	-1.29	-1.71	-1.71	-2.06
2003	February	0.25	-1.14	-1.14	-1.17
2003	March	0.81	-0.91	-0.91	-0.94
2003	April	0.25	-0.72	-0.91	-0.81
2003	May	-0.03	-0.55	-0.81	-0.73
2003	June	0.14	-0.34	-0.65	-0.47
2003	July	2.17	0.74	0.74	0.72

A period of prolonged drought started in August 1997 and ended completely in July 2003. During this period the drought gets weaker at different time durations e.g. February, May, June 1999 and July 2001 the values of all indices show wet conditions. The detailed information of this historic drought is given in Table-2.

Table -2 Period of drought August 1997-July 2003

The difference between 3-Month and 6-Month scale could be understood from Table-3(a) and (b). In this table some of the drought events are represented for same year and month for both scales. The purpose is to show the difference in values in both scales. A 6-month scale will make a calculation based on the information of the past 6-Months of precipitation and soil moisture.

Similarly the 3-Month scale will use the information for past 3months.

Table-3 (a) Calculation of Indices with 6-Month Scale

Table-3 (a) Calculation of Indices with 6-Month Scale

Year	Months	SPI	SSI	MSDIe	MSDIp
1987	April	-0.46758	-1.2898	-1.2898	-1.48462
1991	December	-2.16782	-1.72765	-2.16782	-2.46164
2000	April	-2.15697	-1.2898	-2.15697	-2.57015
2001	March	-1.71482	-2.15697	-2.15697	-2.85762
2005	September	-0.92792	-0.82861	-1.30524	-1.11464

Table-3 (a) Calculation of Indices with 6-Month Scale

Year	Months	SPI	SSI	MSDIe	MSDIp
1987	April	0.416937	-1.03736	-1.16088	-1.12719
1991	December	0.135469	0.416937	-0.20399	-0.2649
2000	April	-0.41694	-1.03736	-1.72765	-1.3529
2001	March	-1.48354	-1.03736	-2.16782	-1.98867
2005	September	-0.82861	-0.82861	-0.92792	-1.09311

A correlation analysis has been done for values of SSI and MSDI with SPI. Table 4(a) and (b) shows that for 6-Month scale there is a good correlation between the values of Indices in comparison to 3-Month scale.

Table 4 (a) Correlation for 3-Month scale

Regression Statistics	SPI vs SSI	SPI vs MSDIe	SPI vs MSDIp
Multiple R	0.56	0.86	0.87
R Square	0.31	0.74	0.76
Adjusted R Square	0.31	0.74	0.76
Standard Error	0.77	0.47	0.45
Observations	442	442	442

Table 4 (b) Correlation for 6-Month scale

Regression Statistics	SPI vs SSI	SPI vs MSDIe	SPI vs MSDIp
Multiple R	0.73	0.92	0.93
R Square	0.53	0.85	0.86
Adjusted R Square	0.52	0.85	0.86
Standard Error	0.63	0.38	0.36
Observations	439	439	439

Conclusion

Drought is a repetitive climate extreme in Sindh Province of Pakistan. The devastating impacts of drought remain for a long time than other natural hazards. Drought monitoring based on single indicator does not provide accurate information. In this study a multivariable approach presented by [4] is used to study the agriculture and meteorological droughts in Sindh. It has been found that a single index is not sufficient to provide overall drought information. MSDI based on the joint probability of SPI and SSI is found to be a reliable indicator for overall drought monitoring. The results of MSDI comply with [4] and indicate that the drought onset prevails with SPI and persistence follows SSI with high drought severity shown by MSDI when both SPI and SSI show drought conditions. The results also show that meteorological drought develop quickly and terminates early while agriculture drought persists for some time.

Acknowledgments

We are grateful to Global Integrated Drought Monitoring and Prediction System (GIDMPS) for providing the drought information and PMD and NASA for providing the precipitation and soil moisture data for our study.

Acknowledgments

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CALCULATION OF CROP WATER REQUIREMENT FOR MAJOR FOOD CROPS IN PAKISTAN BY USING WEAP

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ABSTRACT

As it is well known fact that Pakistan is an Agriculture Country and this sector contributes considerably in terms of economy and GDP of the Country. Since the population of the country is increasing at an enormous rate of 2.3% per annum, therefore we would need to feed more mouths in future. To maintain the status of Food Secure Nation, it is must to increase the productivity of food crops i.e. Wheat and Rice. Since Agriculture sector is the main consumer of water, increasing agriculture would result in more consumption of water at the cost of other sectors, with limited renewable water resources, therefore it is necessary to determine the increasing requirement of agriculture sector to produce more food crops and to formulate the schedule for deliverance of the required water. For this Purpose the area under the food crop has been determined from Report published by Government of Pakistan Statistics Division, Federal Bureau of Statistics (Economic Wing) under name and style of "Crop Area and Production" and has been projected for next 15 years period. For calculation of potential Evapotranspiration, Temperature data from 2000 to 2016 has been collected from Pakistan Metrological Department (PMD) for three station namely Hyderabad, Bhawalnagar and Jehlum because they are installed at regular interval in the fields where Rice and Wheat are cultivated, and is averaged to determine the mean temperature, then potential reference Evapotranspiration was calculated using Blaney Criddle method. The data was inserted in Water Evaluation And Planning (WEAP) software and simulated. The results shows that area under cultivation and water consumption of Food Crop has been increased enormously in past 10 years, and would require more water in future to maintain the current increasing production rate. The only option left to follow increasing production trend with limited amount of water is to increase the efficiency of the System and to adopt water conservation techniques at farm level.

Keywords

Blaney Criddle method, Evapotranspiration, PMD, WEAP.

Introduction

Pakistan is regarded as having agrarian economy and agriculture is considered as largest sector in the country, engaging most of the Labor force and contributing heavily towards GDP. Pakistan is 4th Largest Producer of Rice and 7th Largest Producer of Wheat in the world. This blessing is the gift of Himalayan, Karakoram and Hindukash mountainous ranges. Most of the water is contributed by the snow melts from these mountains and conveyed to the different part of the Country through River Indus and its tributaries. Increasing population is huge challenge for the country and to satisfy the needs of increasing population and to secure the status of food secure nation it is very necessary to continue the increasing trends of food crop production, increase in production is essential to ensure physical access to food at all times [1], ultimately more area under cultivation would definitely require more water, with limited renewable water resources. There are two seasons of food production in Pakistan namely Kharif and Rabi, Rice and Wheat are major food crops of Kharif and Rabi season respectively, therefore are chosen for the study. Water Evaluation and Planning software package is a relatively new approach towards water resource and planning and it is incorporated with number of methods to calculate the agriculture, municipal and industrial water demands and to compare the demand with supply for management of available water resource. The main objective of this Study is to assess the increasing trends of water demand for growing Food Crop in the country and to suggest the way hoe this demand can be fulfilled in future, with limited resource available [2].

Literature Review

Rainfall

Pakistan has Tropical Arid and Semi- Arid Climate, where rainfall is neither regular nor sufficient, wide range of variability in rainfall amount can be found while considering different regions, as Baluchistan experienced 125 mm of Rainfall annually while 750 mm of annual Rainfall occurs in Northern Western Region of the Country. Most of the Rainfall approximately 65 % – 75 % occurs in monsoon season which starts from June and ends in September. These rainfalls are also cause of Major Floods in Sindh and Punjab Provinces [3]. Therefore Rainfall cannot be relied for growing crops except in Barani Areas, where it is primary source of water for growing crop, all other areas need artificial application of water as Irrigation for cultivation.

Water Resource Situation In Pakistan

Mainly water is contributed by River Indus and its tributaries, which are accounted for 138 MAF annually, out of which 110 MAF is diverted annually for Irrigation through canals. 84 % of Supply received in summer (Kharif) season and 16 % of Supply is received in spring (Rabi) Season, and is managed through gigantic Dams and Reservoirs in the Country. There are three main reservoirs in Pakistan namely: Terbela, Mangla and Chashma, the capacity of reservoirs are reduced due to continuous siltation therefore raising project for reservoirs are implemented and some are in pipe line. Beside the availability of Surface water Pakistan also has great potential for Groundwater, it is estimated that 50 MAF of potential Groundwater is available and is exploited up to extent of 38 MAF [4].

Climate of Pakistan

As discussed earlier, Pakistan has tropical type of Climate, with very hot summer and relatively cool summer except in Northern areas, where summer are relatively cooler with snowfall is experienced in winter. Pakistan is situated at north of Tropic of Cancer and also has continental climate conditions, with sharp variations daily as well as seasonal. The hottest recorded temperature is 53.5 °C, which is also considered as highest ever recorded reading in continent of Asia. Monsoon and Western Disturbance are two major factors for precipitation in summer and winter season of Southern Plains respectively [5].

Available Land Resource of Pakistan

The most important natural resource available to Pakistan is its arable Land, Pakistan has 31.7 Mha of arable Land and currently only 20.8 Mha is under cultivation, whereas 80 % of under cultivation land is under Irrigation [6].

Area Under Cultivation of Food Crops

The Wheat is main staple crop and then comes the number of Rice, the area under cultivation of these two crops fluctuates but following increasing trends in long run. When 27 years of data is analyzed under linear trend line, the value of R2 obtained is 0.811 for Wheat crop and 0.7709 for Rice, which means the area under cultivation of these two crop are on increasing trends and is increasing with each passing year. Therefore linear forecast function can be used to predict the area under cultivation in future.

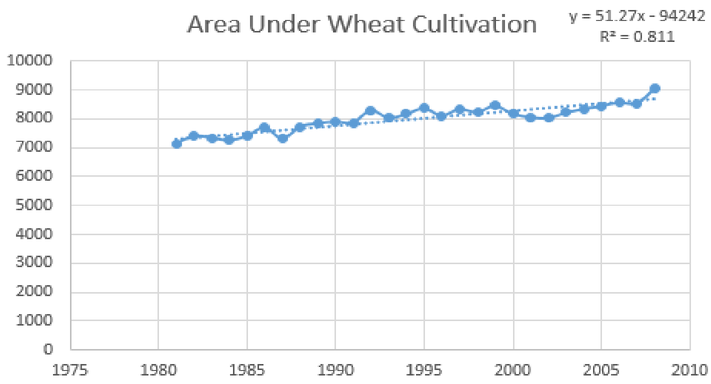

Figure 1: Time Series of Area under Wheat Crop in Pakistan

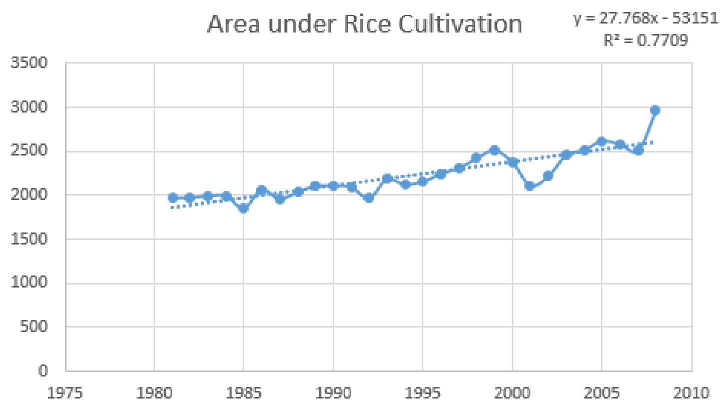

Figure 2: Time Series of Area under Rice Crop in Pakistan Source: Federal Bureau of Statistics

Temperature Data from Pmd

The Temperature data was collected from PMD, from 2000 to 2016, reveals that the temperature of the country decreases with the change in Latitude from South to North, but the annual trend of average monthly temperature is comparatively identical. This means that the Evapotranspiration needs of same crop grown in northern parts would be less than that of southern parts, since temperature is main function on which Evapotranspiration depends.

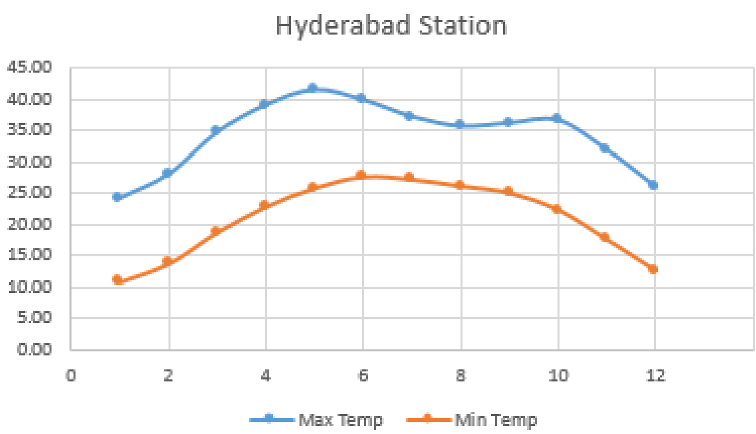

Figure 3: Average Monthly Temperature in Hyderabad.

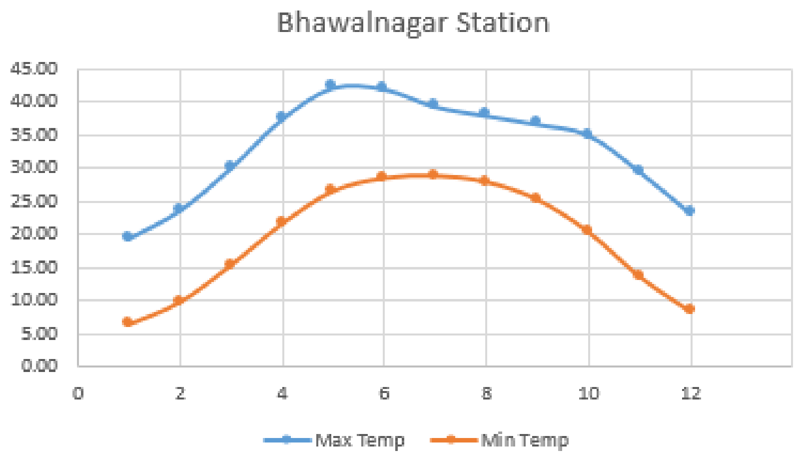

Figure 4: Average Monthly Temperature in Bhawalnagar.

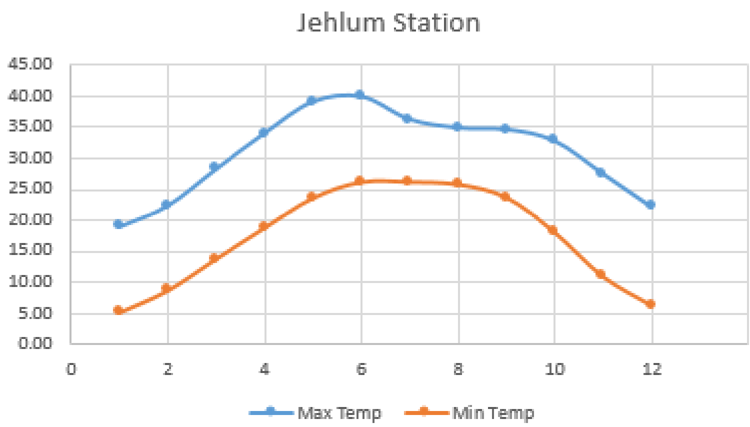

Figure 5: Average Monthly Temperature in Jehlum.Source: Pakistan Metrological Department.

Materials and Methodology

Study Area

Study area selected for this Study are the fields of Sindh and Punjab where Wheat and Rice are sown.

Data Procurement and Processing

The Data required for this research includes: Time series of annual area sown under Wheat and Rice, Average Monthly Temperature of Pakistan and Crop Coefficients for Wheat and Rice.

Annual Area Under Wheat and Rice

The Time series of annual Area sown under Wheat and Rice was obtained from Report Published by Pakistan Bureau of Statistics, the characteristics of the statistics are discussed in section 2.4 and found convenient for linear forecasting hence linearly forecasted up to 2025.

Average Monthly Temperature

Average monthly Temperature was required to calculate Reference Evapotranspiration by Blaney Criddle Method, therefore the average monthly temperature for three Station namely: Hyderabad, Bhawalnagar and Jehlum was collected from 2000 to 2016 from Pakistan Metrological Department (PMD) Karachi. The reason for selection of these three stations was that, they are located approximately at equal distance from each other, spatially distributed in the irrigated fields of Pakistan, since the temperature of Pakistan decreases with the increase in Latitude, therefore they are selected for estimation of average Temperature of Pakistan. For Statistical details read section 3.

Eto Calculation by Blaney Criddle Method

Blaney Criddle method is simplest one to calculate the Reference Evapotranspiration with least amount of data available, it is best for estimation of approximate amount at gigantic spatial level. The equation used is function of average temperature and Daily percentage of annual day time Hours, further the latter variable is the function of Latitude of the area.

The Blaney Criddle fomula:

$$ETo = p\,(0.46\,Tmean + 8) \text{--------------(i)}$$

Month	p	T_Max (°C)	T_Min (°C)	T_Mean (°C)	ETo mm/day
Jan	0.2393	20.86	7.47	14.165	3.4729
Feb	0.25	24.67	10.73	17.7	4.0355
Mar	0.27	30.99	15.94	23.465	5.0744
Apr	0.29	36.8	21.05	28.925	6.1786
May	0.31	40.88	25.31	33.095	7.1994
Jun	0.32	40.57	27.42	33.995	7.5641
July	0.3108	37.58	27.42	32.5	7.1317
Aug	0.3	36.17	26.63	31.4	6.7332
Sep	0.28	35.83	24.68	30.255	6.1368
Oct	0.2592	34.81	20.27	27.54	5.3583
Nov	0.2392	29.64	14.09	21.865	4.3203
Dec	0.2292	23.8	9.12	16.46	3.5698

Crop Coefficient

Crop coefficient can be defined as the ratio of actual and reference Evapotranspiration of Crop, and it varies with the crop stage, ten daily crop coefficient calculated by ullah etal 2001, was converted into monthly and then used in the model.

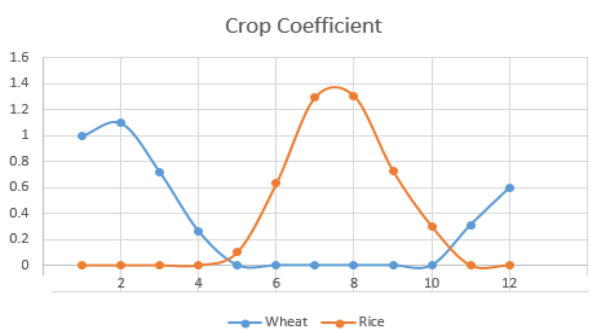

Figure 6: Average Monthly Crop Coefficient for Wheat and Rice.

Results and Discussion

Study Area

The results shows that the Potential Evapotranspiration need of wheat and Rice is 19.69 inch and 35.95 inch respectively. The Area under Wheat and Rice was 18.10 and 4.59 Million Acre in 1981 and was 21.52 and 6.44 Million Acre in 2008 and expected to increase up to 23.67 and 7.61 by 2025 respectively. In the same way the potential demand of water for wheat and rice has been increased and is further expected to increase significantly from 29.70 MAF and 13.76 MAF in 1981 to 38.85 MAF and 22.80 MAF in 2025 respectively. These results are showing the potential demand rather than actual one. The actual demand is always greater than the Potential demand, because much of the water is lost while conveyance, distribution and application. Evaporation is also one of the source of major losses. The increasing trends of demand can be analyzed from the graph shown below.

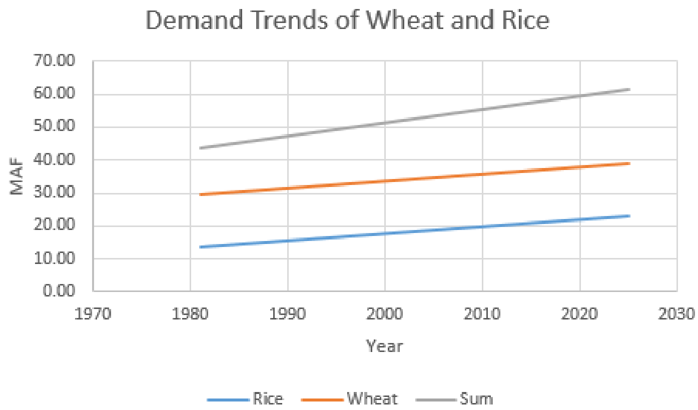

Figure 6: Increasing Annual water demand of Food Crop.

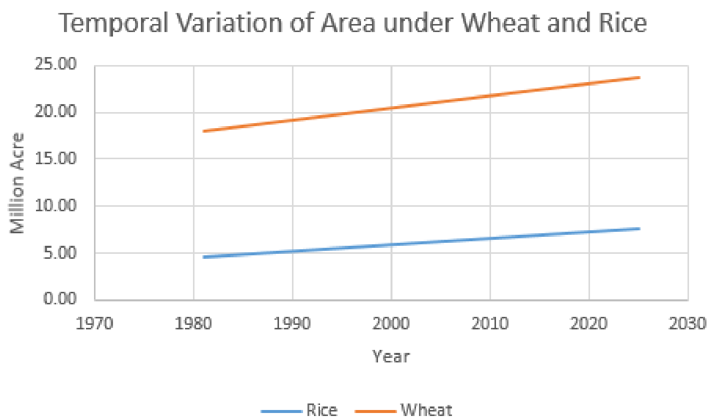

Figure 7: Increasing cultivation Area of Food Crops

Conclusion

As stated earlier Pakistan has large area which is not under cultivation but can be cultivated if water can be made available, the greatest problem being an agrarian country is availability of Water. The water resource is contently limited and increasing population is one of the reason due to which Pakistan is slipping towards water scarcity. To avoid the situation of Food insecurity and water scarcity it is must to made the system efficient, and to reduce the loss of water as much as can be. Keeping in view the Population growth it is must to increase the food crop production so that food insecurity could be avoided, the only option left is adapt with the High Efficiency Irrigation System to get maximum advantage with available water Resource

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WATERSHED DELINEATION AND MORPHOMETRIC ANALYSIS OF SAN NAI BASIN USING GIS AND RS TECHNOLOGY

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ABSTRACT
Watershed management is said to be the basic planning unit of all hydrologic analyses and designs. Watersheds are natural hydrological entities that cover a specific land surface from which the rainfall runoff flows to a defined drain, channel, stream or river at any particular point. Nowadays, watershed management has gained the top most importance in water resources sector necessitating delineation of watersheds. In the present study, the watershed of San Nai stream located in the district of Jamshoro, Sindh, Pakistan is delineated using Arc Hydro Tools 10.1 and HEC GEO-HMS extension. The digital elevation dataset (DEM) is obtained from USGS Earth explorer. Raster analysis is performed to generate data on flow direction, flow accumulation, stream definition, stream segmentation, and catchment delineation. Then the HEC GEO-HMS tools are used to find out the various characteristics of the Sann Nai watershed such as longest flow path, river length, centroid, centroidal flow path. The area of San Nai watershed is found to be 365 sq.km and the length of San Nai stream is found to be 37.61 km. The longest flow path and centroidal flow path are 68.6 km and 34.3 km respectively.

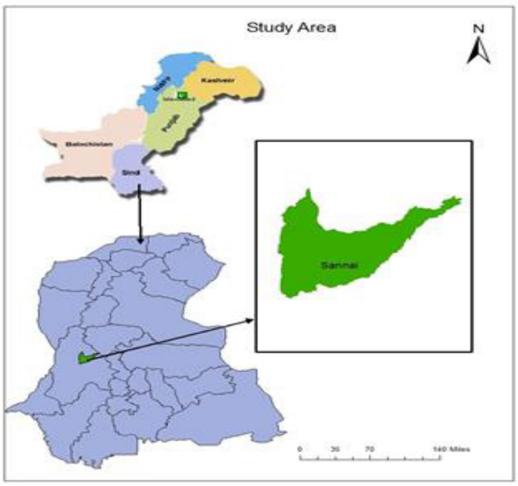
Keywords
Watershed management, Watershed Delineation, Sannai stream, DEM.

Introduction
Earth is called the 'blue planet because water holds a critical role in the Earth system. Water also involves in the major scientific theories and findings. In recent years, a greatly increased emphasis has been placed on improving and maintaining the quality of our national water resources, not only that; water shortage problems are also becoming issues of significant importance. To overcome the water shortage problems, individuals, government originations and agencies need to collaborate and work extensively for providing solutions which cater the need of countries agriculture and domestic demand with focusing environmental aspects of sustainable structure. One of its key aspects which

predicts hydrological events is to model the watershed .The science of hydrology holds a unique and central place in the field of environment, intimately intertwined with other water-related disciplines such as meteorology, climatology, geomorphology, hydrogeology, and ecology. (Sivapalan, 2003) This article seeks to establish broad base concept for delineating different watershed from remote sensing data using GIS techniques. Sann Nai watershed is selected as study area because it plays vital role in huge contribution of water in Rainfall season, leading to extreme flood events. While modelling its watershed will help us predict and determine next hydrological events. The San Nai watershed lies at the 25°56'27.5"N 67°52'08.4"E. The Elevation of the watershed ranges from 120 ft to 1900 ft above mean sea level. The climate of the area can be classified as Sub-Tropical and the major crops grown in area are cotton, rice and maize in Kharif rainfall season. Aster Global digital elevation model provided by NASA in the format of Geo-Tiff are used to extract topographic feature and to delineate watershed, sub-watershed, overland flow. The objective of the paper is to delineate the watershed the Sann Nai stream and to calculate its various characteristics such as catchment area, length, longest flow path, centroid elevation, basin slope and centroidal flow path.

Literature Review

Historically, watershed boundaries were delineated by hand with the aid of contour maps. This process is labor intensive, slow, tedious, inconsistent and error-prone. “A watershed is an area that contributes flow to a point on the landscape.” (Bolstad, 2005).Watersheds are an important focus of study because management of water volume and quality soil conservation, flood control, wild life habitat and forests require understanding the many features of relevant watersheds. Thus, watershed modeling is an ideal application for GIS. A key component of watershed modeling is determining the drainage area that contributes flow to that point on the landscape, doing so requires identifying channels and divides and delineating watersheds. Now-a-days, ArcGIS software is commonly used all over the world to delineate watershed and calculate the various hydrological attributes of the watershed.Lindsay et al., (2008) have identified two main applications of automated watershed delineation as (i) mapping or modeling spatial phenomena; and (ii) developing statistical relationships between basin characteristics and outcome variables related to hydrology or water quality for prediction purposes. Sarhadi et al (2012) delineated watersheds in ArcGIS using the Arc Hydro extension for a regional flood frequency analysis application (ArcGIS Resources, 2013). Jarvie et al (2002) delineated sub-watersheds upstream of 60 sampling stations within the Humber catchment in the United Kingdom using ArcGIS. The objective of the study was to determine linkages between watershed attributes and chemical concentrations measured at the sampling sites in order to observe trends in water quality across the basin. The watershed boundaries were delineated using topographic data provided by the Institute of Hydrology Digital Terrain Models and several functions from the Spatial Analyst toolbox in ArcGIS. Then they assigned attributes to the watershed polygons including catchment area, average elevation, average slope, annual rainfall, several geological characteristics and land use properties and explored the relationships between the attributes and water quality parameters measured at the sampling sites. The relationships were analyzed using a combination of scatter plots and regression analysis.



Study Area

The area selected for the present study is San Nai watershed located in the district of Jamshoro, Sindh, Pakistan. The San Nai watershed lies between latitudes 68º 8’ 23” and 67° 48’ 44” N longitudes 26° 2’ 37” and 25° 55’ 39”. The average annual temperatures at 10m, 30m, and 50m are 27.3, 27.2 and 27.2. Jamshoro is the region of sustainable wind. The wind varies from minimum 6.9 m/s to maximum 9.9 m/s. (PMD, 2005).

Methodology

The four SRTM 1-Arc second DEMs having coordinates N24 67E, N24 68E, N25 67E and N25 68E are downloaded from USGS Earth explorer. These four DEMs were then mosaicked. The various terrain preprocessing tools available in the Arc Hydro Tools (i.e. Flow direction, Flow accumulation, stream definition, stream segmentation, catchment grid delineation) were run in the sequence on the mosaicked raster to delineate the watershed for our study area. Further vector analysis was done to extract the watershed and stream network for the San Nai stream. Moreover, HEC GEO-HMS tools were used and the project was generated. The various characteristics of the San Nai watershed such as river length, centroid, longest flow path and centroidal flow path were then determined.

Results & Discussions

The present study encompasses morphometric analysis of the San Nai watershed. The morphometric analysis of the drainage basin and stream network plays an important role in understanding the the geo-hydrological behavior of drainage basin. The various characteristics of the San Nai Watershed are calculated using HEC GEO-HMS tools as shown in Figure 3 and Figure 4. The centroid of the watershed is commonly calculated by two methods; Center of Gravity and Longest Flow Path. In this approach, the centroid was calculated using flow path method. The values of the San Nai basin area, river length, longest flow path, centroidal flow path, and basin slope are given as follows.

Table 1. Characteristics of San Nai Watershed

Catchment Area (Sq.Km)	River Length (Km)	River Slope (m/m)	Basin Slope (%)	Longest Flow Path (Km)	Centroidal Flow Path (Km)
65	37.61	0.000042	14.45	68.6	34.3

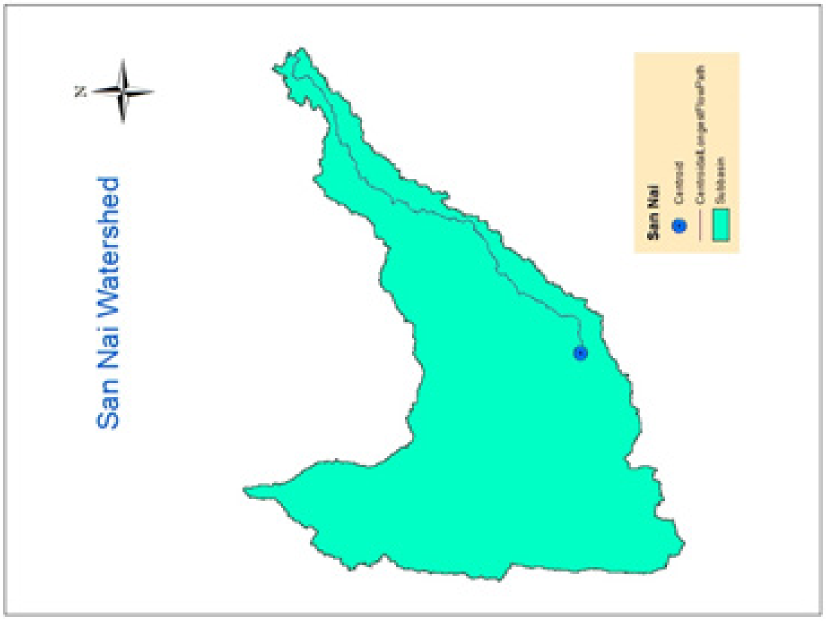


Figure 2 Centroid and Centroidal Longest Flow Path

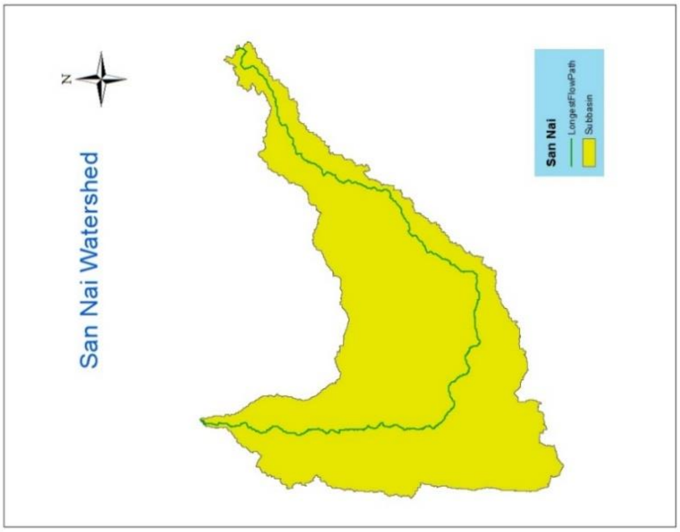


Figure 3 San Nai Basin with Longest Flow Path

Conclusion

The paper reveals that GIS and RS technology is a quick and excellent approach for watershed delineation and determination of various characteristics of the watershed. On the other hand, the manual approach for watershed delineation using contour maps is time consuming, inconsistent and error-prone. In this study, the watershed was delineated for San Nai stream using Arc Hydro tools and the watershed characteristics were determined using HEC GEO-HMS tools. The catchment area of San Nai stream was determined to be 365 sq.km.

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GROUND WATER QUALITY ASSESSMENT OF BHIRIA CITY

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ABSTRACT
Safe drinking water is basic human right of Public. Public health in rural Sindh is at high risk due to excessive use of contaminated groundwater. Many waterborne diseases are caused by water contamination. This study aims to assess quality of groundwater for drinking purpose. The research was conducted in Bhiria city of District Naushero feroze to assess groundwater quality. The twelve locations of hand pumps were selected for sampling including samples of Rohri canal and nearby lakes (waste water disposal ponds).The Temperature, pH, turbidity, EC and TDS (Total dissolved salts) were analyzed using YSI instrument and Turbidity meter. The results revealed that pH ranged from 7.18 to 9.04.The temperature of ground water was satisfactory averagely up to 28˚c.The turbidity ranged from 0.45NTU to 283NTU, TDS ranged from 235mg/L to 2925mg/L, EC of samples ranged from 375(us/cm) to 4652(us/cm).The analysis showed that hand pumps near contaminated lakes have high values of EC and TDS as compared to WHO standards and PEPA(Pakistan environmental protection agency).Hence not fit for drinking and results of samples near Rohri canal hand pumps have satisfactory results within the drinking limit standards. The lake it-self has higher values of EC, TDS and turbidity. So due to excessive seepages from lakes and Rohri canal respectively, might make groundwater unsuitable and suitable for drinking respectively.

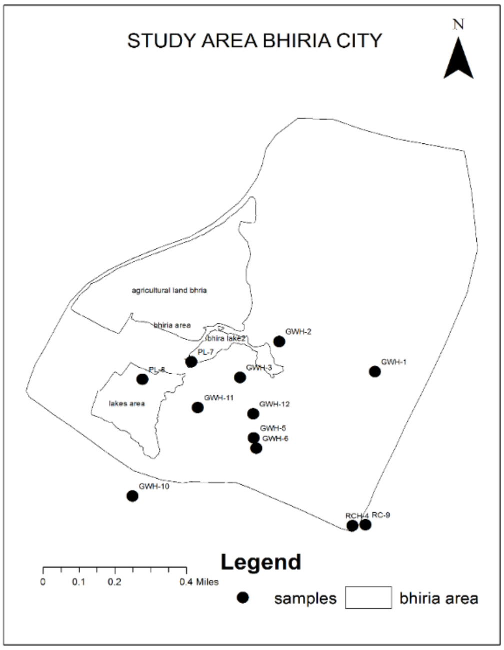
Keywords
Water, Quality, Assessment

Introduction
Water is essential for all living organisms in the world. Despite of its importance it is most poorly managed resources in the world (Fakayode, 2005). A specific amount of water is needed for all human beings, animals and plants for various purposes. The two main sources of water are groundwater and surface water. The first one is available below ground in saturated zone and other one is present at surface of earth. Though water available at earth is in large quantity but fresh water out of it is less than 3%.
Almost one third of world's population utilizes groundwater for drinking purposes. But unluckily developing countries of Africa and Asia are not getting safe drinking water. Out of 6 billion population on earth almost one billion people are not accessible to safe drinking water (TWAS., 2002). Urban development and human activities are the reason for contamination of groundwater. The contaminated groundwater consumed by community created water borne and water related diseases.
Recently, a main concern is given to control quality of water, since human health is influenced by quality of water (Gadgil, 1998): Dixit and Tiwari 2008). In developing countries deteriorated quality of water has resulted diarrhea (Thompson, 2003), hepatitis E (Rab, 1997). Many researchers stated that Arsenicosis, Anemia, Diarrhea, Cholera, Fluorosis, Guinea, Worm disease, Typhoid, HIV/AIDS are the water borne diseases (M.A. Zeenat,2015;Sinclair, 2009).

The important indicators of safe water drinking quality are Turbidity, Ph., Ec and TDS. The increasing inclusion of silt, clay and organic suspended particles increases the turbidity. The Ph of water directly or indirectly affects the drinking water quality, high value of Ph causes irritation of eyes, skin and mucosal membrane due to direct exposure. Electrical conductivity and TDS represents the total amount of anions and cations in the water. However some toxic ions like As, fluorite and nitrate may also be present in water which are toxic to human. Although major ions beyond some limits have adverse effects on human health. (Shahid, 2015)

The groundwater quality in domestic use should be tested to know its suitability for humans consumption. It is necessary to examine above mentioned problems in an environmental structure in which quality and quantity of water resources is of great concern. This study aims to assess drinking water quality in various locations of Bhiria city particularly near polluted lakes and Rohri canal.

Materials & Methods



In this study area twelve samples were collected from hand pumps of different locations including samples near the polluted lakes, lake itself and near the Rohri canal. Pre sterilized polythene bottles were used for collection of samples. The Standard methods of sample collections were applied. The analysis of samples was done to determine its parameters like temperature, ph, Ec, Turbidity and TDS. The samples were analyzed carefully using YSI instrument and Turbidity meter available in the U.S Pakistan Center for Advanced studies in Water Jamshoro. Then tables were prepared showing results of all samples collected and tested in laboratory.

Results

S.NO	SAMPLE CODES	TDS mg/L	EC µs/cm	PH (Mole/L)	TURBIDITY (NTU)	TEMPRATURE(˚C)
1	GWH-1	1313	2104	7.65	0.45	33
2	GWH-2	1047	1666	7.83	1.47	32
3	GWH-3	1930	3086	7.23	1.97	33
4	GWH-4	1450	2315	7.71	0.99	33
5	GWH-5	1092	1742	7.22	1.18	32
6	GWH-6	252.85	399	7.4	0.42	32
7	GWH-7	2041	3275	7.18	1.85	33
8	GWH-8	1247	2080	7.25	1.90	32
9	RCH-9	235	375	7.72	1.03	32
10	RC-10	257	406	8.12	86.4	33
11	PL-11	2840.50	4523	9.04	264	32
12	PL-12	2925	4652	8.67	283	33

TABLE 1: Results of samples of Bhiria City District Naushero Feroze.

Discussions

Physio-chemical parameters (Temperature, Ph, Turbidity, Ec and TDS) of studied water samples are summarized in table. This indicated that temperature of collected water was normal ranging from 32˚c to 33˚c. The Ph value was satisfactory ranging from (6.5-8.5) except the sample (PL-11,12) of polluted lakes having results of 9.01 and 8.67 respectively. The turbidity level of all samples were below the permissible limit (5NTU) given by WHO and PEPA ((NSDWQ), 2008) (Oyedele, 2009)) except the samples of Rohri canal (RC-10) and polluted lakes (PL-11,12) having values 86.4, 264 and 283NTU respectively. Electrical conductivity was analyzed for all collected water samples in which almost all sample values exceeded the adequate range except samples of Rohri canal and hand pump near Rohri canal (RC-10,RCH-9,) having values within the range specified by WHO and PEPA. The WHO standard and PEPA has specified the limits of Ec below 1000 µs/cm. TDS were also exceeded the specified limit by WHO and PEPA except samples of Rohri canal and hand pump near Rohri canal (RCH-9, 10)which were within the range of 1000mg/L.

Conclusion

The results summarizes the conclusion that almost all samples have higher values then allowable range except the samples of hand pumps collected near Rohri canal because of fresh water infiltration near Rohri canal. Whereas polluted lakes are highly contaminated due to which hand pumps near polluted lakes have also high values of TDS and Ec which are not suitable for drinking.

Acknowledgments

Authors are thankfull to Ms. Hadiqa Maqsood (Asistant Professor) at USPCAS-W Jamshoro for her technical guidance throughout the Research work.

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APPLICATION OF GIS AND HEC- RAS IN FLOODS FORECASTING: A CASE STUDY OF LOWER INDUS BASIN, SINDH 2010

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ABSTRACT

Flood is one of the most disastrous natural calamities that causes an irreversible amount of damage followed by the loss of assets. The aberrant trends of rainfall is considered as root cause of flood occurrence that can exacerbate due to lack of actual flood forecasting and subsequent mitigation. Even with the extensive amount of researches and findings in flood forecasting control of flood is not an easy task especially in developing countries where resources and expertise have always been a major issue. Remote sensing and GIS has emerged as one of the most innovative tool for efficient flood inundation mapping, flood hazard and flood risk mapping. Therefore, this study is aimed to integrate the remotely sensed data in geometric module of hydrodynamic river modeling and analysis tool namely: HEC-RAS (Hydrologic Energy Center – River Analysis System). In this study ALOS World 3D - 30m" (AW3D30) DSM was used, which is the most recent freely available digital elevation/surface model. Land Cover derived Manning's roughness coefficient, cross-section interpolated bathymetry and upstream flow hydrograph were parameterized in the model. An unsteady flow analysis was undertaken run for a period of 1 month. Within the river model, the calibration was done by comparing the observed and simulated stages at the peak flow whereas the inactive flood plains calibration is done by comparing with the daily captured remotely sensed MODIS image. The model was duly calibrated and validated for 2010 flood. The study demonstrates the flood risk maps along with the identification of vulnerable zones, with respect to the flood characteristics (depth, velocity, depth time velocity, arrival time and duration). Therefore, the study aims to conclude that with few modifications the newly launched DSM data can be used in flood simulation. Consequently, based on the extracted results, potential vulnerable spots can also be identified.

Keywords

Flood forecasting, Flood Risk mapping, DSM, Remote Sensing, MODIS.

Introduction

Flood is 3rd most devastating hazard after storms and earthquakes in the globe [1]. Pakistan, being one of the most vulnerable country to natural calamities is primarily a flood prone country [2] [3] [4]. With diverse geographical, topographical and climatic regions, Pakistan is always prone to multiple hazard that include earth quake, land sliding, droughts, sea intrusion, cyclones and floods [5]; [6]-Flood is the frequent disaster [7]. Since its existence, country has encountered about 38 floods; 50% of the floods were categorized as major floods causing enormous damages to socio-economic stability of the country [8].

Climate change and global warming has been a main culprit of disasters; Pakistan received an unexpected extreme rainfall events during July to September 2010 that ultimately led to disastrous throughout the country [9]. The flood was ranked as the worst since 1929. According to National Disaster Management Authority (NDMA), report, twenty million people were affected by these floods and rains. In addition, flash floods and land, due to rainfall, resulted severe harm to infrastructure in the affected areas. Whole villages were drowned, many downtowns were underwater, dwellings were ruined, and thousands of acres of yields in the field and agricultural lands were spoiled with major soil erosion resulting in some areas [10].

Furthermore, various studies also confirmed the event, occurred in 2010 was a result of exceptional rainfall events. Sindh being lower riparian of Indus basin was an equal victim of riverine flood. The massive riverine flood navigated towards an already stressed embankments; as a result the embankments were undermined or completely damaged in some cases [11]. This caused a he economical clash, social distress and an irreversible ecological damage. With modern technologies and innovations, flood forecasting with flood routing through modeling technique has emerged as an effective and widely used tool for flood control and damages mitigation. Furthermore, with integration of GIS (Geographic Information System) in hydraulic modeling has significantly edified the efficiency and validations of these models with ground realities. This geospatial technique has significantly revolutionized the concept of flood inundation mapping, flood forecasting, flood damage assessment and development of decision support systems [12]. Therefore, present study aimed to establish a hydraulic model of below-Kotri reach of the Indus River by the integrating the remotely sensed DSM (Digital surface model) for preparation of flood inundation maps followed by damage assessment of the region.

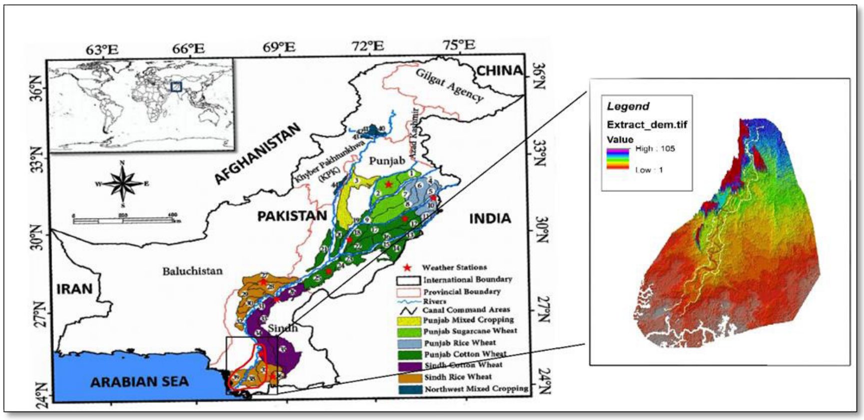

Figure 1 Location map of study area with (inset) topographic view

Study Area

The study area is located in the Southern part of the county having coordinates 25° 26′ 32″ N, 68° 19′ 0″ E, comprising the last reach of the Indus River (Fig. 1). With the total area of 15,458.75 km2, it covers the vast and important agricultural and ecologic zones of the lower Indus basin. It starts from Kotri barrage and opens into the Arabian Sea [14].

The area has relatively flatter terrain and low lying lands. The portion of the land mostly receives very low rainfall ranging only 150 to 200 mm, annually and is categorized as semi-arid region of the country [14]. With its high dependency on irrigation network, river and its canals are the major source of fresh water in the region. The area is frequently prone to critical floods. Covering the major portions of Thatta, Sujawal, Jamshoro and Hyderabad districts, the study area possess historical, agricultural, urbanized and environmental importance.

Materials and Methods

Datasets and Software

1. ALOS World 3D – 30 m (AW3D30) Digital surface model (DSM) was acquired from: http://www.eorc.jaxa.jp/ALOS/en/aw3d30/index.htm and was used for topographic and geometric extractions

2. Daily discharge data was acquired from Sindh Irrigation Department (Kotri barrage sub division) from 2000 to 2015.
3. Land use land cover (LULC) data was extracted from land cover atlas of Pakistan: Sindh province (joint venture of SUPARCO, FAO and Govt. of Sindh).
4. Data about flood controlling structures was obtained from Sindh Irrigation Department.
5. Google Earth pro for ground trothing.
6. Arc-GIS 10.3.1, HEC-GeoRAS and HEC-RAS 5.0.3 were used for preprocessing and analysis.

Flood Model

The acquired DSM was preprocessed in Arc-GIS to fill the gaps and loops in the data. Individual tiles of the DSM were mosaicked and then area of interest was clipped. The clipped area was then converted from raster to TIN format using 3D analyst tool in ArcMap environment. Existing alignment of the embankments was digitized in Google Earth Pro and then it was imported in Arc-GIS for further processing.

With the help of HEC-GeoRAS extension the bathymetry was extracted and flow paths were assigned accordingly (Fig. 2).

HEC-RAS 5.0 allows generating a terrain model in RAS Mapper directly based on ".tif" extension (Fig.3). The geometric features of 1D file were overplayed and used for defining the geometry of the 2D model.

With the application of observed and extract geometric data from HEC-GeoRAS, the terrain model was further refined in order to overcome the unrealistic elevation spikes in the DSM. With further incorporation of flood protection embankments, square to octagonal mesh of the area was generated (Fig.4).

Mesh is further redefined to analyze the water surface elevation along the embankments. Finally the unsteady flow analysis was undertaken with daily flow values from 15th august 2010 to 15th September 2010. The followed methodology is also briefly in Fig.5.

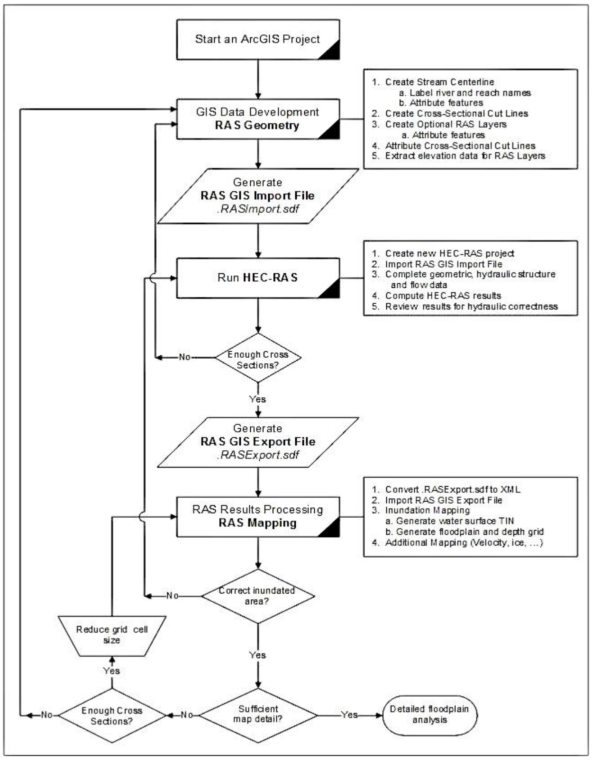

Figure 2 Detailed flow chart of HEC-GeoRAS execution [13]

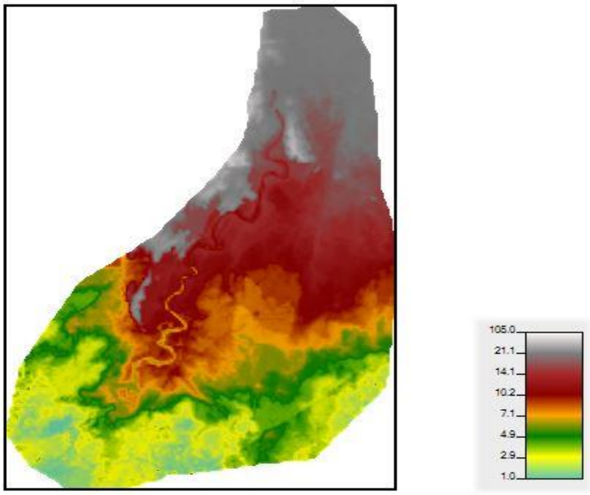

Figure.3 Initial terrain based layer of the study area

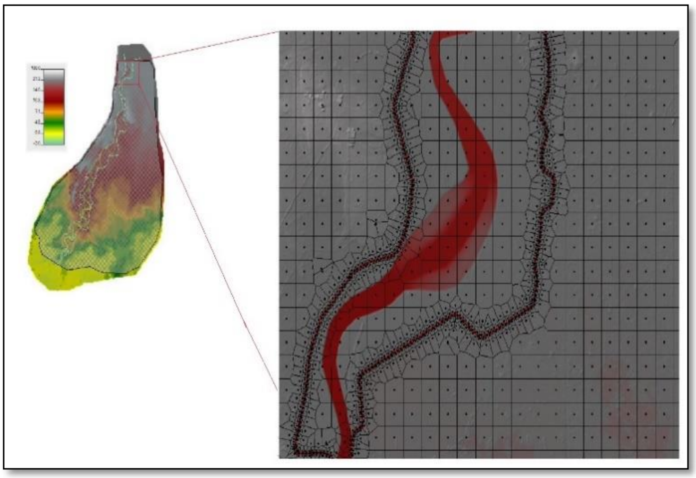

Figure. 4 Mesh generated in geometric editor of HEC-RAS

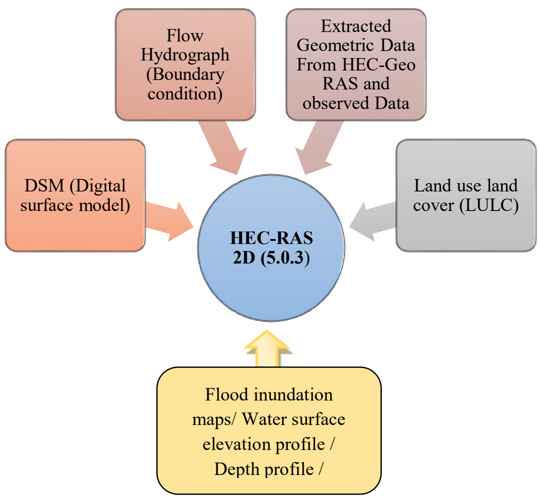

Figure.5 Flow chart of study

Results

The established model was initially calibrated with normal flow conditions and then verified with the flows reaching to medium flood levels (hydrograph reaching to 3.5 lac cusecs). No major inundation or overtopping was observed along the embankments, the water depth map and water surface profile is highlighted in Fig.6 and Fig.7 (a & b).

The observed profile's WSE (water surface elevation) were exceeding at few places over the terrain profile but it was not high enough to inundate the embankments along both sides as shown in Fig.6. Few spikes were also observed in the right bank terrain profile showing mountains along the bank of the river. The main concern, in most of the cases, regarding flood forecasting, is the time of arrival of flood water and the depth of water approaching to an area with in that prescribed time. HEC-RAS with all the latest versions from 5.0 has a variety of mapping options available to justify the users demand and to predict the arrival time maps of the region (Fig.8), provided the LULC of the region must be available.

After the successful trials the model was run with the real hydrograph values measured at downstream of Kotri barrage in 2010 floods by Sindh irrigation Department. With the time step of 1 hour the model was simulated for a period of almost one month starting form 15th August 2010 to 15th September 2010.

As 2010 flood was no doubt one the biggest flood disaster by this region, causing a vast and unsettling damages in the regions. The flood inundation extents in the region defines new records which were not experienced from decades. The inundation maps and water surface profile formed from the simulation also attest this situation in an efficient way. Thanks to the embankments provided on the both sides otherwise flood would had devastated the whole region in glimpse as shown in Fig.9.

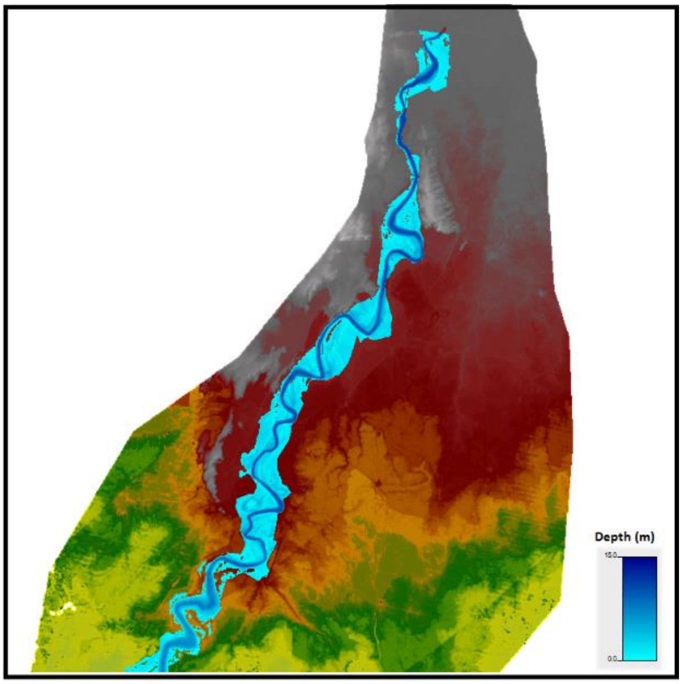

Figure.5 Flow chart of study

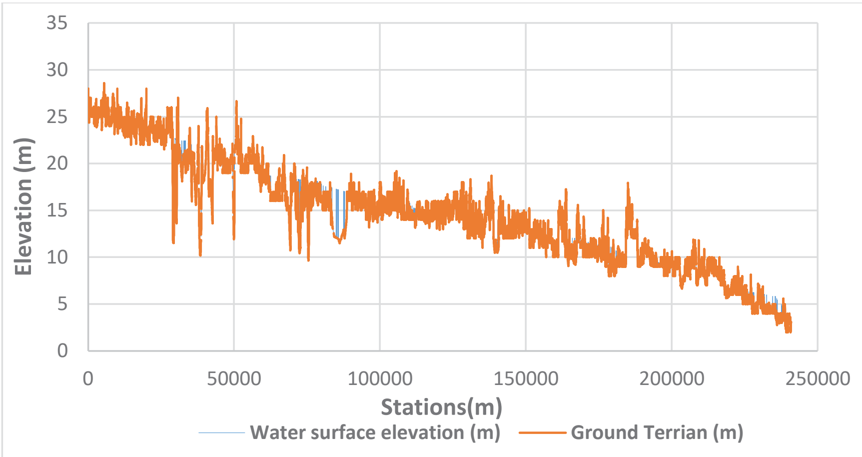

Figure.7 (a) left bank WSE vs Terrain profile at 10000 cumecs.

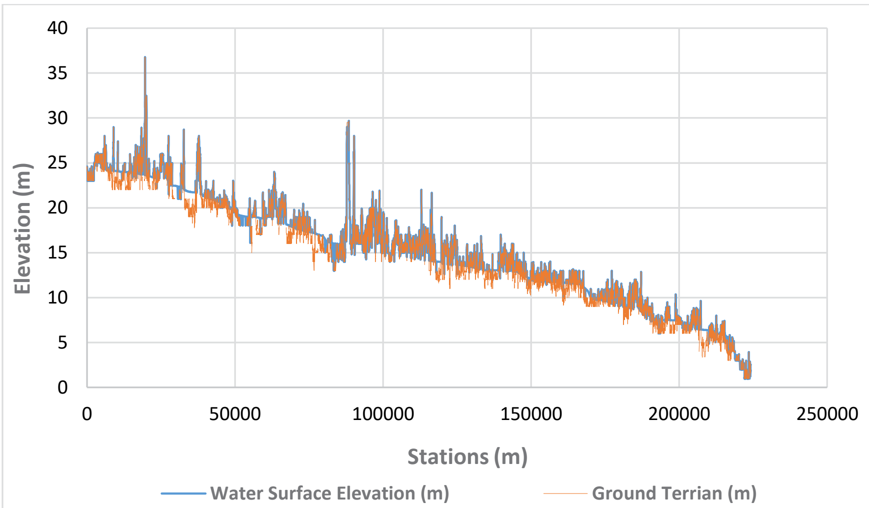

Figure.7 (b) Right bank WSE vs Terrain profile at 10000 cumecs

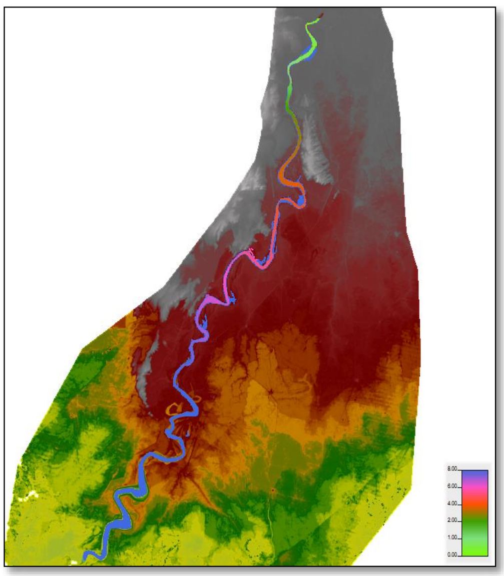

Figure.8 Arrival Time Map at 5m Threshold Depth in days

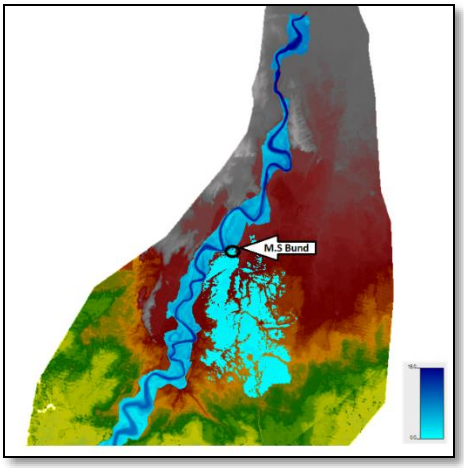

Figure.9 Inundation map at 10.30 pm. (Dated: 2-9-2010)

With the introduction of breach at M.S bund the model produced satisfactory results as compared with inundation extent read from MODIS Aqua (250 m Bands 7-2-1) of the same date.

However, unfortunately, the period of simulation falls in the time span when cloudy weather conditions were prevailing over the study area and was impossible to extract the exact extent of inundation from MODIS images. Nonetheless, with the availability of later clear images of following days, the maximum extent resemblance was done by visual interpretation of the results with observed MODIS image. Whereas, the identification of breach location was done on the basis of terrain vs WSE profile produced by the model and dually verified by the SPOT satellite imagery published by SUPARCO.

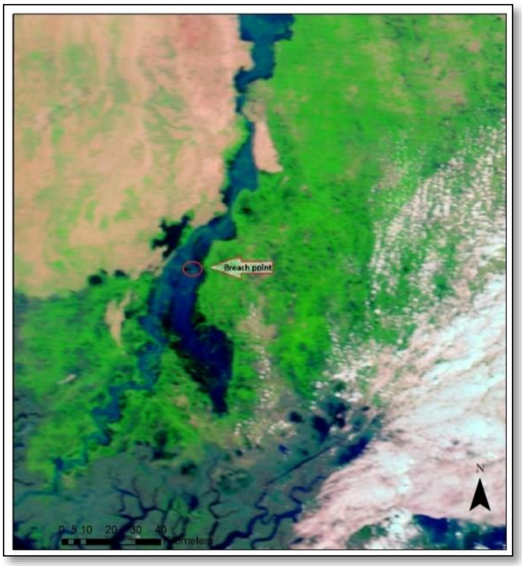

Figure.10 Modis Aqua Image Dated: 2-9-2010

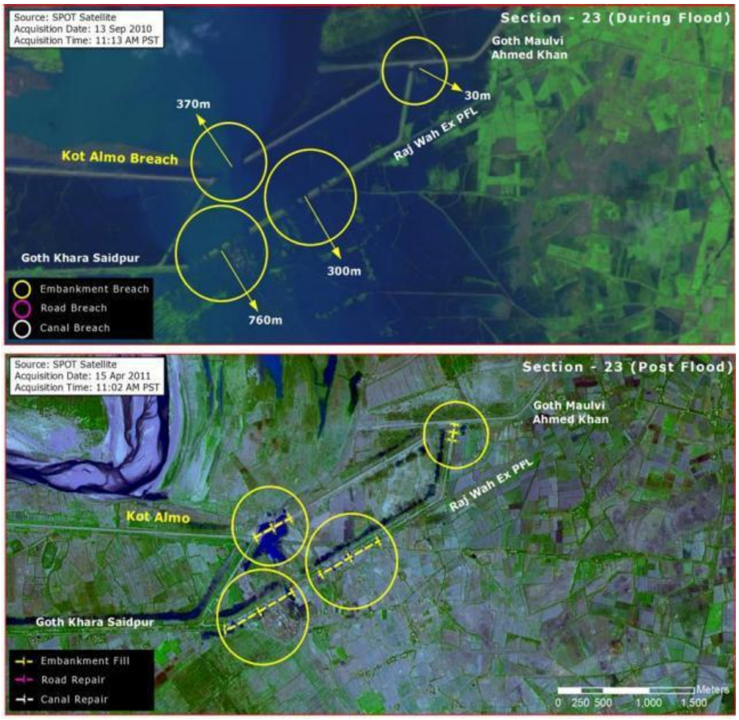

Fig.11 SPOT Satellite Images 2010 [11]

The simulation results and terrain of the right bank along with bunds elevation proved as safer side with respect to the left side. It could also be verified from visual observations that the left side has various desperations and more meandering sections near to the embankments, which makes it more vulnerable to flood induced breaches. The case of M.S bund breach is same because it is located at very closer to the meander section of the river and failed due to hammering action of water (Fig.12).

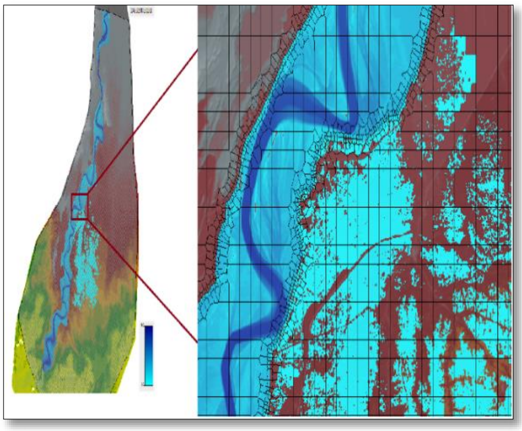

Figure.12 Breach location existing at river meandering section

The extent map along with water surface elevation map and arrival time map of the particular date (2-9-2010) was extracted and compared with the daily MODIS Aqua satellite imagery (Fig.13). The comparison shows that simulated results are matching with that of the satellite imagery. By further inspection it was observed that as the executed model is based on the 30mX30m digital surface model which doesn't bear detailed terrain information of the small attributes.

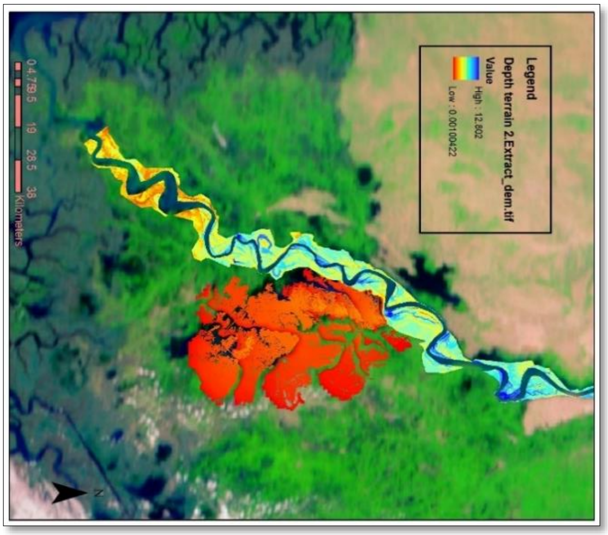

Figure.13 Flood extent map in comparison to MODIS Aqua

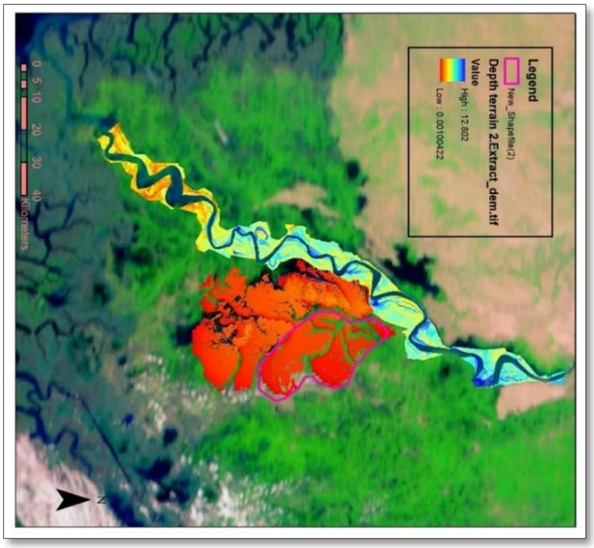

Figure.14 over Simulated Portion

Conclusion

In this study an attempt was made to integrate the geospatial data with 2D hydrodynamic model for simulation of flood event. Based on results it is concluded that freely available DSM can be used for representation of Indus River bathymetry. Moreover, the predictions made with measured flow data can be sufficiently matched with satellite data and inundation maps made with this model can be used for thorough investigation of the flood inundation extents.

Consequently, it is suggested that more reliable and comparable results can be achieved if fine resolution DSM/ DEM is used along with cloud free images of the area under question.

Acknowledgement

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EVALUATING THE IMPACTS OF SCARP AND PRIVATE TUBE WELLS ON IRRIGATED AGRICULTURE COVER USING REMOTE SENSING AND GIS TOOLS IN DISTRICT MATIARI

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ABSTRACT

Government of Pakistan is attempting several remarkable steps to improve agricultural yield and make it sustainable. Salinity control and reclamation project (SCARP) is one of those effective initiatives launched in 1980s in Sindh province to reclaim waterlogged and saline lands by setting up large-scale ducts and tube wells. But unfortunately the government could not afford operation and maintenance of wells in 1990's which caused farmers to install private tube wells. In this connection, this paper evaluates impacts of SCARP and private tube wells on agriculture cover using remote sensing and GIS tools in Matiari district. The Satellite images of Landsat-5 of 1989, 1990 (prior to SCARP), 1993, 1998 and 2009 are analyzed with two separate techniques of image processing in ArcGIS i.e. the normalized difference vegetation index (NDVI) and unsupervised classification. The results showed that agriculture cover has increased in Rabi by 12% and 18% in 1998 and 2009 while 8% and 12% in Kharif season of 1993 and 2009. It is inferred that agriculture cover has increased more in 1993 and 1998 that is short period after installation of wells as compared to 2009 which is long period after installation. Field survey revealed that no other major change was observed before 1990s except installation of tube wells under SCARP project. Hence the above results witness SCARP and private tube wells satisfactorily increased the agriculture cover in Rabi and Kharif season because, always the increase in quantity of irrigation water is the main cause of increase in agriculture in water shortage locations.

Keywords

Agriculture cover, Remote sensing, NDVI, and SCARP wells

Introduction

Remote sensing is widely applied discipline of both science as well as arts that uses satellites moving around the earth to extract its spatial and temporal data of numerous entities. Whereas ArcGIS is a tool that analyzes remote sensing data to extract several features and phenomenon happening on the earth spatially and temporally like urbanization, Forest, agriculture land, water, soil, barren land and etc. [1]. The proper future planning, monitoring and management of natural resources can be made successful with the help of highly accurate spatial and temporal land cover data [2].

It has vast applications in research and academia being carried at almost all institutes and industries. One of the most important research application that is also used in this paper is the analysis of multi spectral and thermal mapper remotely sensed satellite data on ArcGIS for detecting the change in the land use and land cover (LULC). This is again one among the best soft skills to acquire a high interpretation of the various entities of globe environment without physically touching them i.e. remotely sensed [3]. There are several concepts and methods of change detection that are in practice but broadly ArcGIS is incorporated with three techniques i.e. vegetation indices, unsupervised classification and supervised classification. Now a days many researchers prefer use of these techniques in their research because the data requirement is ready made available on internet sources. Another reason is attractive graphical user interface of analysis tools that is again handy and friendly in use with high accuracy and reliability in results that best represent the real world scenarios [4]. There is a variety of vegetation indices like Normalized difference vegetation index (NDVI), Soil adjusted vegetation index (SAVI), Difference vegetation index (DVI), Ratio vegetation index (RVI), etc. to detect the portion of land covered by agriculture in a certain satellite image of any location and specially to monitor the growth and the health of crop. Generally NDVI is a ratio of vegetation that is employed to indicate greenness or yellowness of crop that helps in monitoring its health and ability of yield. The well growing and healthy plants absorb red light more and less reflect near infra-red (NIR) light while dead plants reflect red light more [5], thus NDVI is calculated as difference ratio of these two lights for each pixel in a satellite image as follows.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

The other technique of change detection is unsupervised classification in which the pixels of same nature are grouped together. The same type of pixels are detected by computer software itself like iso-cluster processing technique is used in ArcGIS to cluster pixels of similar features. NDVI and unsupervised classification technique is used in this paper for assessing the crop cover because it’s easy in interpreting its values for various land use classes and these are also widely used in research pertaining to climate change and earth environment [6].

Meera Gandhi, et al. successfully detected the change in land cover as a case study of Vellore district of Tamil Nadu using NDVI and unsupervised classification techniques. Their results showed the decrease in forest and barren land by 6% and 23% respectively, whereas vegetation, urban and water areas have increased by about 19%, 4 % and 7% respectively from 2001 to 2006 [7]. Yuan and Elvidge worked out change detection and pattern of expansion of urbanization in Washington D.C, USA with the help of NDVI differencing, maximum likelihood supervised and unsupervised classification techniques using remote sensing and ArcGIS [8].

Several investigators and researchers have validated the satisfactory use of change detection techniques like NDVI, maximum likelihood supervised and unsupervised classification to monitor growth and health of agriculture [6]. NDVI is the best parameter to assess and monitor droughts [9, 10]. Furthermore it can also be used to assess the agricultural droughts at global, national and water bodies’ command area level [11, 12].

Government of Pakistan is taking several remarkable improvement steps towards sustainable and improved agriculture yield. However the present canal network of irrigation delivery system brought an incredible escalation in waterlogging and salinity since next half of the 19th century around Indus river basin. To address such problems, Salinity control and reclamation project (SCARP) is one of effective initiatives launched by government of Pakistan in 1960s to set up a large-scale tube wells, surface drains, interceptor and tile drains to cover 8 million hectares with approximate cost of $2 billion. This projected was started in 1980s in Sindh which initially reclaimed the lands successfully but unfortunately the power supply shortages and poor governance after few years of operation of wells could not afford satisfactory operation and maintenance. This situation caused the farmers to install a large number of tube wells of their own to mitigate mentioned issue and increase irrigation and crop production [13]. In this connection this article is aimed to assess the impacts of SCARP and Private tube wells on agriculture cover in the Rohri canal command in Matiari district of Sindh province, Pakistan.

Methodology

Study Area

The research study area lies around 25.8271° N, 68.3816° E as representative coordinates, located in Matiari district, Sindh, Pakistan as shown in Figure 1. The district was upgraded from taluka to district level in 2005 and according to 20011 census it has population of about 738,322. It covers a gross area of about 142800 hectares out of which about 93000 hectares at present are under cultivation (CCA).

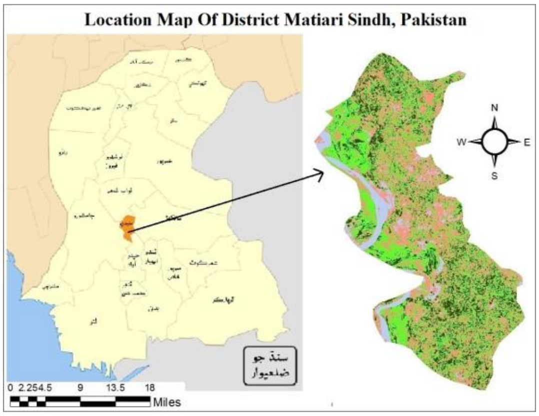


Figure 1. (Location Map of Study Area)

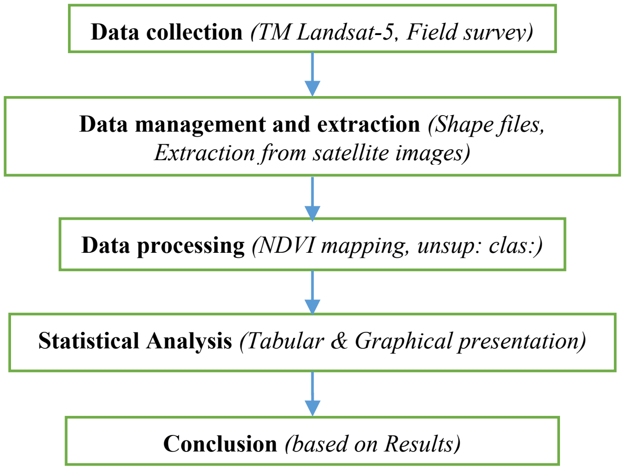
Site Details from Field Survey

A Field survey is conducted for this study in order to know various elements installed at site related to agriculture and water resources. The survey states that there are two main sources of irrigation in selected district, one is use of surface water run by the Rohri canal taking off from left side of Sukkur barrage and other is groundwater extraction through SCARP and Private tube wells. In this district the SCARP project was started in 1985 to install number of tube wells to control waterlogging and salinity along the Rohri canal command but the operation of the tube wells was observed in 1990. The profile of SCARP tube well showing technical data and date of operation is shown in figure 2. This picture is taken from one of tube well's site during field survey. The tube wells (i.e. SCARP & Private) are installed at various depths and having different diameter of pumping pipes ranging from 70 ft. to 220 ft. deep and 4 in. to 9 in. diameter respectively. The field survey revealed that there is not salinity problem particularly in this district but only the waterlogging is rising, Also water drawn by wells is of suitable quality therefore farmers are using for irrigation to meet surface water shortages and hence controlling waterlogging. The survey conducted from progressive farmers few months ago (i.e. January, 2017)

exposed the shortage of surface water therefore they are more switched to and relaying on groundwater. After a few years of installation of SCARP tube wells, the government could not afford the proper monitoring and provision of enough electric power, hence the farmers started installing diesel supplied tube wells on their own.

Figure 2 (Profile of SCARP Tube well)

Flow Chart of Methodology



Data Collection

The remote sensing data required for this research analysis is satellite imagery in order to achieve the objectives of study. As this paper evaluates the impact of SCARP and Private tube wells therefore the change detection has to be determined before operation of wells (i.e. before 1991) and after a few years of operation. In this connection, the cloud free multispectral images of Landsat 5 TM sensor has been acquired from the United States Geological Survey (USGS) through online sources (https://www.usgs.gov/) as shown in Table 1.

Table 1. Landsat imagery data

Land use Classes	Range of NDVI Values
Water bodies	> 0
Barren land i.e. rock & soils	0 – 0.2
Low vegetation	0.2 – 0.4
High vegetation & Forests	>0.4

Analysis Tools

In this paper two analysis tools are used one is ArcMap version 10.3.1 for processing digital data to convert it into understanding of vegetation and other land uses. Second is excel used for statistical analysis of output results obtained from ArcMap. Furthermore ArcMap creates maps and attribute tables (showing results) while excel help in interpreting these results by performing statistical analyses and draw tables & graphs.

Processing Approaches

The change detection in agriculture cover of mentioned study area is analyzed with two different approaches, though there many other techniques but these two are less data driven and the availability and acquiring of data is so easy. One of the technique used in this paper is normalized difference vegetation index (NDVI) while other is unsupervised classification using iso-cluster. All the above mentioned satellite imageries are processed individually for creating both NDVI maps and unsupervised classification.

Analysis Processes

NDVI Approach

NDVI is determined using band 3 and 4 of Landsat 5 because these are Red and infra-Red respectively as per above given formula in introduction section, hence the NDVI is determined using image analysis tool in Arc-MAP which follows the above mentioned formula of NDVI. This tool generates raster layer showing NDVI values in stretched format i.e. only max and min values without having attribute table which contain the number of pixels for different ranges of NDVI values. Thus in order to generate the attribute table, firstly the raster image is classified in required number of classes using symbology option. In this research article the classes are made based on values recommended by National Aeronautics and Space Administration (NASA) for different land uses. According to NASA very low values ranging from 0.1 and below express the soils, rock, snow, or barren land. Slightly negative and positive values approaching zero represent water bodies. Moderate values ranging from 0.2 to 0.3 correspond to grassland and shrub. High values ranging from 0.6 to 0.8 represent forests areas (https://earthobservatory.nasa .gov/Features/MeasuringVegetation/). In this paper following classes are made based on these recommended values as shown in Table 2.

Table. 2 Classification based on NDVI values

Land use Classes	Range of NDVI Values
Water bodies	> 0
Barren land i.e. rock & soils	0 – 0.2
Low vegetation	0.2 – 0.4
High vegetation & Forests	>0.4

After creating above mentioned classes in the NDVI raster layer, now further it is reclassified using reclassify option in spatial analyst tools (Tools – spatial analyst tools – re-class – reclassify). This reclassify process generates again another raster layer showing NDVI values containing attribute table which dictate the number of pixels intercept by each provided classes. This is basically indication of the areas of different land covers for each year. The area is converted into units of area (i.e. acres, hectares, sq.km etc.) by multiplying them with the area of one pixel. Each pixel of band 3 and 4 of Landsat 5 is 30m x 30m resolution, hence multiplication of this with number of pixels gives total area for that particular land cover class. In this way this process is repeated again and again for individual satellite images of mentioned years. In last the attribute tables showing pixel's quantity will be imported in .txt or .csv format for further statistical analysis using excel.

Unsupervised Classification

This technique uses the option of iso-cluster unsupervised classification in the spatial analyst tools (Spatial analyst tools – Multivariate - iso-cluster unsupervised classification). The requirement for iso-cluster unsupervised classification is a raster composited with all seven bands therefore this composite band is firstly generated using image analysis option in windows tab of ArcMap. In this way an iso-cluster raster is generated with 10 classes but again the reclassification is done to combine those classes which are same as discussed above. Identification of same classes in iso-claster layer can be made by matching it with NDVI image and checking the few corresponding locations on Google earth. Afterwards the steps are same as described in NDVI sub section. Only two main classes of land cover (i.e. vegetation and non-vegetation) are made in this particular technique in order to save the time, reduce burden of analysis and meet the objective of research, i.e. change detection in agriculture cover. In the end unlike to NDVI approach, the attribute table will be imported for further statistical analysis using excel.

Results & Discussion

Results of NDVI Approach

All the Landsat imagery data of above mentioned years are analyzed for NDVI individually in order to know the area surrounded by different land uses especially vegetation, and to compare the area of corresponding land use with past years for change detection. Following are the NDVI maps generated for Rabi season as shown in figure 2.

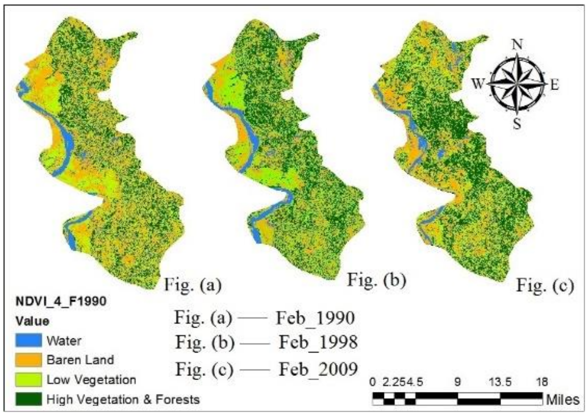


Figure 2. (NDVI Maps for Rabi season)

The above figures (i.e. a, b & c) show the NDVI maps of February month of Rabi season in 19990, 1998 and 2009. Each map is divided in four classes shown with different colors (i.e. see in legend item). It can be visually percept that there is change in crop cover from 1990 to 1998 and from 1998 to 2009. The careful attention on these figures depicts that the agriculture cover has increased in same manner of years. Furthermore it can also be seen from maps that the barren land has reduced in same manner of years. If we look at maps critically we come across to know that barren land has converted a bit to urbanization while greater percent of it has converted into agriculture therefore this is the reason that crop cover shown in map is increased. In addition to that if we again critically look at maps it can also be interpreted that the low vegetation has reduced from 1990 to 1998 and from 1998 to 2009, moreover the map of 1990 and 1998 points out that the place of low vegetation has been occupied by high/dense vegetation. Hence it can finally be concluded that not only the crop cover has increased but also the yield and health of crop has got strength. Similarly following are the NDVI maps generated for Kharif season as shown in figure 3.

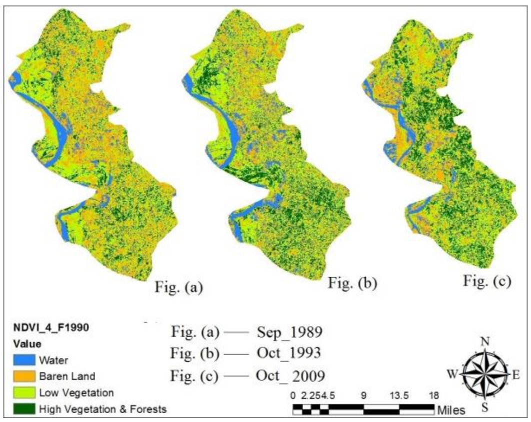


Figure 3. (NDVI Maps for Kharif season)

Similarly the careful attention on these maps realizes the increase in vegetation from 1989 to 1993 and from 1993 to 2009. It also expresses that the barren land has reduced with the time in same manner of years. This conversion of barren land is paid somehow to urbanization and somehow to agriculture side. If we analyze further more critically then we come to know that some of the barren land has converted somehow to low vegetation and somehow to high vegetation from 19989 to 1993 and from 1993 to 2009. In similar pattern some of the low vegetation has converted to high vegetation. This is again an indicator dictating that not only the vegetation cover has increased but the strength of crop growth has also increased which ultimately result in increase in yield.

Statistical Analysis of NDVI Results

The NDVI analysis is reclassified into the required number of classes as mentioned in methodology. Furthermore this reclassification analysis extracts the number of pixels occupied by each class which is then imported in excel sheet. In excel the number of pixels are multiplied with pixel size (i.e. 30m x 30m) to convert it into unit of our choice (i.e. Hectares etc.). The area occupied by different classes of land use in all years of study period separately for Rabi and Kharif season of irrigation is shown below in Table 3.

Table 3. Area occupied by different Land uses

Land Use	Area (hectares)					
	Rabi			**Kharif**		
	1990	**1998**	**2009**	**1989**	**1993**	**2009**
Water	11346	12971	8084	11704	17547	12052
Barren Land	52742	41962	41957	50239	37619	39481
Low vegetation	44141	43762	41014	58196	59343	55921
High vegetation & Forests	34574	44107	51748	22663	28293	35348
Total Vegetation	78714	87869	92762	80859	87636	91270
% increase	…	12%	18%	…	8%	4%

Values of total vegetation show a noticeable increase from 1990 to 1989 and from 1998 to 2009 whereas the barren land is reducing in similar manner of years. The above maps just gave the graphical interface to realize change but it really does not give the exact or approximate numerical value of area for each class or by which the area has changed. Hence the Table. 3 tells us approximate area covered by each class. The table shows that 78714 hectares of study were under vegetation in 1990 in Rabi season while it increased to 87869 hectares in 1998 hence an increase of about 9155 hectares is attained in 1998 that is not a small quantity to be neglected. In same manner it increased by 4893 acres from 1998 to 2009 in Rabi season. Similarly it increased in Kharif by 6777 hectares and 3634 hectares from 1989 to 1993 and from 1993 to 2009 respectively. However the most important statistical parameter that has been worked out is the percent increase in consecutive years of study period, Again the Table. 3 indicates that 12% vegetation has increased from 1990 to 1998 of Rabi season while 18% from 1990 to 2009. It means change from 1998 to 2009 is only 6% which is less with respect number years (i.e. 11 years gap) where as it increased by 12% from 1990 to 1998 in lesser time period (i.e. 8 years gap) as compared to 6% in 11 years. Similar trend has also been observed for Kharif season, it has increased by 12% and 18% from 1990 to 1998 and from 1998 to 2009 respectively.

The Figures. 4 & 5 shown below present above mentioned Table. 3 in the graphical form. It can be viewed from both the graphs that the bar of total vegetation is increasing temporally from years 1993 to 2009 in Rabi season while from 1989 to 2009 in Kharif season. If it is viewed bit more analytically, it clearly tells that vegetation has increased more from 1990 to 1998 in comparison to increase from 1998 to 2009. Same strategy is also observed in years of kharif season that total vegetation has increased more from 1989 to 1993 in comparison to increase from 1993 to 1998. It realizes that certainly a certain change has been brought in the field from 1989 which increased the vegetation suddenly in short period.

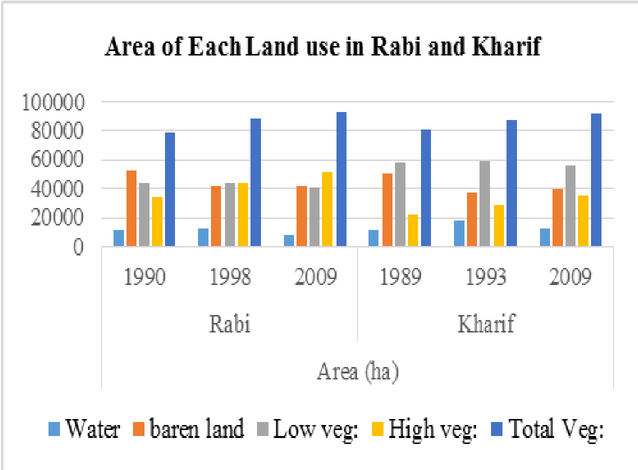


Figure 4. (Graph showing area of each land use in Rabi & Kharif)

Furthermore the Figure 4 points out that the barren land has reduced temporally from 1990 to 1998 and from 1998 to 2009 in Rabi while it has also reduced in same manner in years of Kharif season.

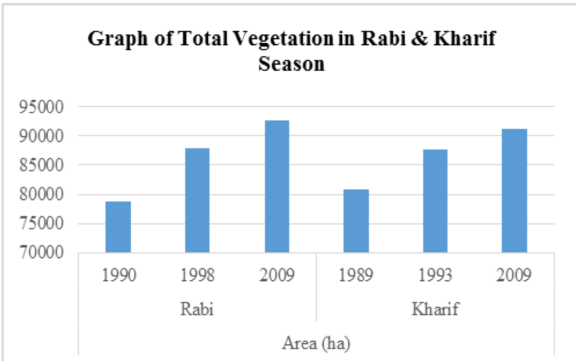


Figure 5. (Graph showing Total vegetation in Rabi & Kharif)

Results of Unsupervised Classification

The unsupervised classification come up with a little change in the results as compared to the NDVI, the change is minute hence it can be neglected. The most important observation in this analysis that matches to NDVI analysis is the exactly similar trend of increase or decrease in land covers with respect to years as we got earlier in NDVI analysis. There is just only difference in area occupied by each land cover class by a little number. The area covered by each land use in years of both Rabi and Kharif season obtained from unsupervised classification technique is shown below in Table 4.

Table 4. Area of different classes for Rabi & Kharif

Season	Year	Vegetation (ha)	Non Vegetation (ha)	% increase
Rabi	Feb_1990	78362	64341	…
	Feb_1998	87310	55292	11.42%
	Feb_2009	92253	50349	17.72%
Kharif	Sep_1989	80431	62172	…
	Oct_1993	86491	55310	7.53%
	Oct_2009	90542	51694	12.57%

Results of Unsupervised Classification

The results of both the analysis i.e. NDVI and unsupervised classification depict that there is increase in agriculture in Rabi season by 12% and 18% from 1990 to 1998 and from 1990 to 2009 respectively. The careful attention on this result reveals that the change from 1990 to 1998 is dominant than change from 1998 to 2009. If we analyze from time point of view (i.e. rate per year), it shows that 12% has increased in 8 years i.e. from 1990 to 1998 or in other sense it has increased at a rate of 1.5% per year. On other hand it has increased by just 6% in 11 years i.e. from 1998-2009. Hence there is sudden change from 1990 to 1998 in short time period as compared to change from 1998 to 2009 despite of long period. Likewise the case is same for Kharif season that the change from 1989 to 1993 is much greater than change from 1993 to 2009. If we analyze from time point of view (i.e. rate per year), it shows increase of 8% in 4 years i.e. from 1989 to 1993 or in other sense it has increased at a rate of 2% per year. Thus there is sudden change from 1989 to 1993 in short time period as compared to change from 1993 to 2009 in long period. Furthermore the field survey dictates that major change that took place in the water resource of field after 1989 was installation of tube wells under SCARP project to cater the surface water shortages and counteract waterlogging and salinity issues. Yet no other dominant change had been brought except this great improvement step taken by government towards agriculture sector. The above results also witnessing that not only the crop cover has increased but the strength of crop has also increased which will ultimately result in increase in yield. Hence it can be inferred from above discussion that the SCARP and privates rube wells working in study area are satisfactorily increasing crop yield.

Generally, now a days farmers have brought shift from conventional to improved techniques of irrigation i.e. from border to furrow, but it cannot be dominant reason, let's assume for time being that this change in method of irrigation has happened then the question does arise, why it has not increased agriculture greatly from 1998 to 2009 and from 1993 to 2009 in Rabi and Kharif respectively? Secondly the survey showed that farmers of the district are complaining shortages of surface water therefore many of them have switched to groundwater and rest are switching slowly and slowly to tube wells after the failure of SCARP wells. In this context, based on above discussion it can be judged that the SCARP tube wells were the main cause of increase in agriculture in the study area. Furthermore if we just concentrate from 1989 to 1993, the percent increase in agriculture is high which is obviously witnessing that initially SCARP wells showed remarkable efficiency but with time it was not well operated and managed by government therefore a decrease in increase percent has been observed from 1993 to 2009 and from 1998 to 2009. In addition to that, the increase from 1998 to 2009 is the efficiency of private tube wells with a little efficiency contributed by a few SCARP tube wells that are still in just lazy operation. In last it can be concluded based on above discussion that change detection in agriculture cover observed in this study area is reason of multiple factors that include SCARP wells, private wells, change in irrigation method, change in fertilizers, etc. But amongst all these factors the SCARP and private tube wells are dominant because always the main cause of increase in agriculture in areas of surface water shortages is the increase in irrigation water like groundwater source in our case.

Acknowledgment

[1] Thanks to SCARP WAPDA of Masu sub-Division and Irrigation Department Rohri Canal Circle in providing data for this paper.

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PERFORMANCE EVALUATION OF HIGH RESOLUTION CLIMATE DATA IN PROJECTING CLIMATE CHANGE: CASE STUDY: PRECIPITATION OVER PAKISTAN.

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ABSTRACT

Downscaled World-Clim 30 arc seconds equivalent to 1 Km spatial high-resolution climate projections are regionally examined over Pakistan. The climatic parameters considered were average annual precipitation and seasonal variation. The global climate model data (GCM) of the CCSM4 model which participated in the CMIP5 (Coupled Modeled Inter-comparison project phase-5) were selected under two RCP (Representative concentration pathways) scenarios i.e. RCP-8.5 and RCP-6. This study focuses on 30 years observed gridded data (19702000) and 30 years future downscaled high resolution World-Clim data (2040-2060). It was observed that maximum average monthly precipitation was found to be 166 mm for thirty years (1970-2000) in Kashmir and Islamabad areas while least rainfall received by Northern Sindh and Baluchistan areas. CCSM4 shows an increase in precipitation for RCP 6.0 and decrease for RCP 8.5 for the future projections. Northern and Southern part of the country showed significant variation while Central part have less variability when compared current and future projections. High Resolution World-Clim downscaled data for CCSM4 has been compared with CMIP5 data that is statistically downscaled having same spatial resolution of 1km and results of both downscaled product was significantly similar.

Keywords

Precipitation, CMIP5, RCPs, World-Clim, Global Climate Models, spatial resolution.

Introduction

Climate change is global phenomenon and man-made activities accelerate the emissions of Greenhouse gases. It will result increase in extreme precipitation events and will cause flooding. The hydrologic response to climate change may effectively impact many water resources. These resources may be domestic, agriculture or industrial [1]. [2] Summarized the crop yield outcomes expose the local patterns of projected climate variables, CO2 effects, and agricultural systems that contribute to over-all crop production. Summarized the crop yield outcomes expose the local patterns of projected climate variables, CO2 effects, and agricultural systems that contribute to over-all crop production. Increase in worldwide surface temperatures are probably going to prompt changes in precipitation and air humidity in light of changes in atmospheric dissemination, a more dynamic hydrological cycle, and increments in the water-holding limit all through the climate [3]. Annual mean rainfall is significantly low in most parts of the dry and semi-arid region of Asia. In Pakistan, 7 of 10 stations have shown a tendency toward increasing rainfall during monsoon season [4]. Generally, global land precipitation has increased by about 2% since the beginning of the 20th century [5]. By mid of this century, more than 20% increase are projected in annual average river runoff and water availability at high latitudes and in some wet areas, and decrease by 10-30% over dry areas at mid altitudes, some of which are water stressed areas By mid of this century, more than

20% increase are projected in annual average river runoff and water availability at high latitudes and in some wet areas, and decrease by 10-30% over dry areas at mid altitudes, some
of which are water stressed areas [6]. Precipitation trends over the country have also increased significantly over the past century [18].

Global Climate Models

World Climate Research Program's (WCRP) Working Group on Coupled Modelling (WGCM), with input from the International Geosphere-Biosphere program's (IGBP) Analysis, Integration and modeling of the Earth System (AIMES) project, have made the archived output of GCMs available freely for download through the Program for Climate Model Diagnosis and Inter-comparison (PCMDI) [7]. The global climate model (GCM) is generally described as the most useful tool with which to predict likely future climatic changes. Global climate models (GCMs) enables to project future changes in climate, but there is a cut off between the spatial scale of GCM output and the scale at which policy and Decision support system can be made [11]. Global Climate Models (GCMs) are the only tool, which may be used for climate projections [12]. Global Climate Models represents earth climate system based on the emissions of Greenhouse gases. GCMs are coarse resolution with grid spacing more than 100 Kilometers. Global Climate Models have been used to simulate historical and projected precipitations for climate change studies. InterGovernmental panel on climate change (IPCC 2007) provides data set of historical and future climate simulations [13]. GCMs based precipitation simulation is uncertain and subjected to biases due to errors in model, input variables, model structure, assumptions and boundary conditions [14]. General circulation models (GCMs) put forward, that escalating concentrations of greenhouse gases may have substantial consequences for the global climate warming. GCMs are restricted to their usefulness for many subgrid scale applications by their coarse spatial and temporal resolutions [15].

Representative Concentration Pathways

A new type of Greenhouse gas emission scenarios have been introduced in the CMIP5 ensemble data, which are more comprehensive than Special Report on Emission Scenarios (SRES) [16]. This study will consider two RCPs out of two RCPs: RCP-8.5 and RCP-6.0. RCPs represent wide range of climate outcomes. The need of RCPs are become more significant because of it is difficult to determine the direction of Green House gases and factors influencing on socio-economic, technological and population growth [17]. The paper is organized as follows; section 2 defines the study area dataset and method used. The results of precipitation projections and precipitation trends are illustrated in section 3. Discussion and outlook are presented in section 4.

Methodology

This study predicts future precipitation trends over Pakistan. Pakistan has experienced some of the hottest and driest conditions in the South Asian region, with the exception of the Upper Indus Basin where cool, moist conditions prevails. There is great spatial and temporal variation in rainfall patterns. As rainfall is one of the most significant and noticeable of all atmospheric processes and essential for survival for all of us, it has not received much Precipitation trends over the country have increased significantly over the past century. This overall increasing trend in precipitation is apparent over most of the regions in the country but future changes in precipitation patterns, due to climate change, are not conclusive. Hence, any changes in the available water resources due to change in precipitation patterns will lead to serious challenges in the environment, food security, and livelihood for millions of poor people. Pakistan is highly vulnerable to the adverse impacts of climate change in the region, which could have serious consequences on water resources, environment, people's livelihoods and food security. There is great spatial and temporal variation in rainfall patterns in Pakistan. Though rainfall is one of the most significant and noticeable of all atmospheric processes and essential for survival for all of us, it has not received much attention from planners, policy makers and researchers in this region. Rainfall has an important role in the evaluation of climatic water balance. Floods and droughts of the past decade have increased concerns about climate change. Therefore, it is the dire need to conduct research on change in precipitation patterns for future so that the country may start planning and preparing for such disasters well advance in time.

The Country Profile

The country has a long longitudinal strip from Northern Himalayas stretching to Arabian Sea in South. Country with a 180 Million people and 70% are dependent on agriculture. Population in central part is dense followed by coastal areas where sea level rise and floods are occurring rapidly consequences of increase in global temperature as the climate shifts [19]. Most parts of Pakistan are arid to semi-arid with great spatial and temporal variability in hydrological parameters like temperature and precipitation. Main source of precipitation is monsoon contributing 59%. Central part of Pakistan is dominated by arid climate [20]. Monsoons and bringing storm from the south are the two main sources of precipitation in Pakistan. Apart from this Pakistan face a severe a drought situation in the previous three decades. [24] Pakistan has extreme weather conditions: hot summers and cold winters. Summer temperature rises to more than 45oC in southern part and due to snowcapped mountains in northern part temperature

fall to less than -10oC. Water bodies and glaciers are greatly affected by climate change in Pakistan. [25] Pakistan experiences 40% to 80% precipitation in DJFM (December, January, February and March) at West and Southwest. Annual Area weighted precipitation of Pakistan is 238 mm in which 140.9 mm is contributed by summer and 25.6 mm contributed by rest of the seasons. [26]

Dataset

The study evaluated the performance of 30 Arc second highresolution world-clim data and compared with downscaled data using downscaling package V3.3 (Mosier 2015) for bias correction and delta downscaling simulations for CCSM4 GCM participating in the fifth phase of the Coupled Model Inter-comparison Project (CMIP5). The included bias correction method are empirical quintile mapping (QM) improving downscaled GCM historic simulations is evaluated through comparing the downscaled GCM simulation's cumulative distribution functions (CDFs) with Global Historical Climatology Network (GHCN) station CDFs for precipitation corrected. These results validate the bias correction methods as a means to improve GCM simulations for the purpose of delta downscaling them. World-clim data consist of gridded data cover the global land areas having datum WGS84.

Data Simulation

World-clim high-resolution average monthly precipitation data freely available for public is extracted for specified study region Pakistan. Current precipitation climate data (1970-2000) from world-clim version 2 and future precipitation climate data (20412060) from world-clim version 1.4 analyzed and differences between future and current data are calculated using ArcGIS. Average monthly precipitation data for monsoon (June, July, August, September) also observed and further the figures are compared with the precipitation amount in non-monsoon months. To evaluate the performance of already downscaled precipitation data is also compared with downscaled data using downscaling package V3.3 (Mosier 2015). Statistical downscaling approach is used to increase the resolution of coarse CMIP5 GCM data. Raw GCM has a very coarse resolution up to 100 km grid, which is not sufficient to project future changes. Delta method of statistical downscaling are used and the resolution are made finer up to 1 km. Delta method of downscaling is simple and widely used for acquiring fine spatial resolution. The precipitation variables from the GCM simulations are arithmetically averaged over an historic period from a control simulation and a future period from scenario simulation to estimate changes.

Results and Discussion

Annual Average Monthly Rainfall

Annual monthly mean precipitation is analyzed for current (19702000) and future (2040-2060) period in Figure 1. Current precipitation map shows high value of 166 mm precipitation in Khyber Pakhtunkhwa and Azad Kashmir region. Most Northern and most Southern part of the country got very less amount of precipitation in past. Central part of the country was not too much dry but still fall in low numbers. Future projection for both scenarios is not too much different from past values but most important is that less area is covered by maximum precipitation events. Both scenarios have increase in precipitation amount but as area is decreasing so, overall there is decrease in precipitation. Both scenarios have too much similarity while analyzing the difference between future and past precipitation. RCP-6.0 shows 54.58 mm increase in Northwest part of Khyber Pakhtunkhwa and 66 mm decrease in Southern parts of Baluchistan. It is cleared from the figure that significant decrease in that parts of the region which have got the maximum precipitation in past. RCP-8.5 also shows too close with 42.66 mm increase and 62.75 mm decrease at the same locations as in the earlier scenario.

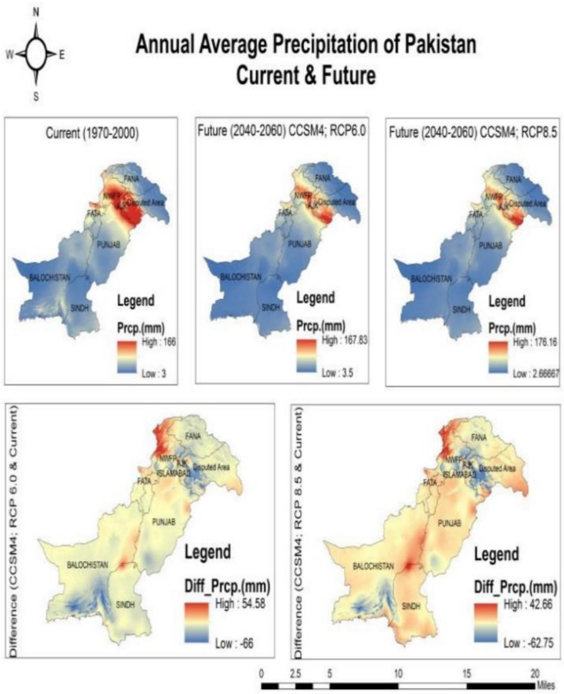

Figure 1(Difference of annual average monthly precipitation)

Monsoon And Non-Monsoon Precipitation

Pakistan is situated on the North of Tropic of the Cancer. Pakistan has continental type of climate described by extreme variation in temperature. The monsoon and western disturbances are the two main reasons, which vary the weather of Pakistan. Monsoon occurs in summer from the month of June till September almost in allover Pakistan. Monsoon brings heavy rainfall and can cause significant flooding. The study analyze the average monthly precipitation of monsoon (June, July, August, September) JJAS and non-monsoon in Figure 2. There is no significant increase in maximum precipitation events while analyzing past and projected maps. There is spatial variation and in past, distribution of maximum precipitation is grater than the projected one. RCP-8.5 shows 376.75 mm precipitations, which is slightly greater than past and RCP-6.0 i.e. 335-mm. Non-monsoon is normally dry and have very less precipitation in Pakistan. Therefore 124 mm precipitation in past years and slightly less 108 mm and 96mm for RCP-6.0 and RCP-8.5 respectively.

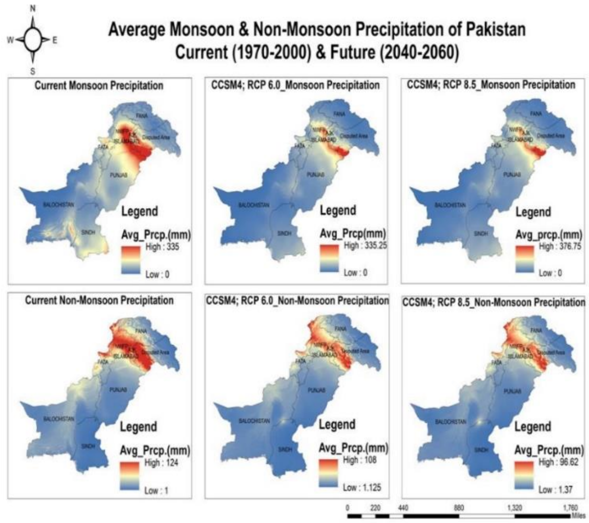

Figure 2 (Average monthly Monsoon and Non-monsoon precipitation of Pakistan)

Comparison of Datasets

To evaluate the world-clim dataset, It is compared with statistically downscaled dataset using downscaling package V3.3. Resolution of both dataset is same (30 Arc second) which will make ease to compare the performance of both datasets. Figure 3 shows the World-Clim dataset and downscaled dataset.

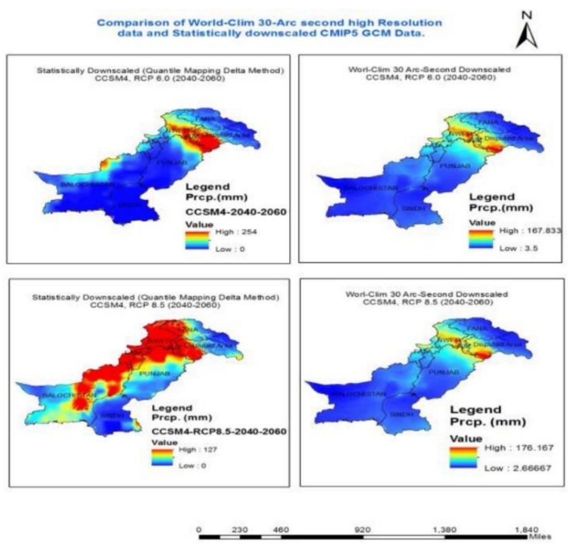

Figure 3 (Comparison of World-Clim 30-Arc second high Resolution data and Statistically downscaled CMIP5 GCM data)

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CLIMATE CHANGE IN THE GULF COUNTRIES: IMPACTS ON VARIOUS HYDROLOGICAL PARAMETERS

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ABSTRACT

Climate change is proved to have detrimental impacts on water resources almost all around the globe. In recent years, climate changing patterns in Gulf countries have started to cause extreme temperatures which in turns effect occurrence, intensity and interval of rainfall and drought. This trend is expected to continue in the future. To predict the climate change in gulf countries, downscaled General Circulation Models (GCM) 'GISS-E2-R' was selected and analyzed under a concentration scenario using ArcGIS 10x. The model showed the possible changes in temperature and precipitation patterns for the period 2041-2060 under Representative Concentration Pathways (RCP) 6.0 which was presented in Intergovernmental Panel on Climate Change 's (IPCC) fifth assessment report in 2013. The modelling results are then compared with current conditions (1960-1990) and the difference is calculated. The analysis showed an increase in temperature across the region which might prove too hot for the human beings. On the other hand, an overall decrease in precipitation can be predicted from the result of analysis and modelling. The spatial change in temperature and precipitation is depicted through thematic maps. Thus, this study could guide policy makers and researchers of this region to take suitable actions to devise policies and take necessary steps to cope with the changing climatic patterns, mitigate its social impacts and secure its water resources.

Keywords

Climate Change, Gulf Countries, RCP6.0, GCM, Temperature, Precipitation.

Introduction

According to various scientists and climatologists there is a clear picture and scientific evidences about the warming of earth and that warming is causing variation in the climatic patterns [1]. Climate change is said to have growing detrimental impacts on freshwater systems worldwide and it is predicted that the area of land facing the issue of rising water stress will become greater than twice that the area of land with diminishing water stress by 2050 year [2] as Intergovernmental Panel on Climate Change (IPCC) report on climate change states that from the mid of 1970 there is rise in temperature which is to be in the average of 0.15 degrees Celsius per decade at global level.

According to Fourth Assessment Report by IPCC, almost all around the globe, climate changing patterns have started to affect occurrence, intensity and interval of extreme temperature, rainfall and drought over the late 20th century and this will tends to continue in future [3],[4]; these warming and maximum temperatures are caused by the anthropogenic activities which have also been identified as contributor to extreme precipitation at the global scale. Extreme temperatures not only affect natural processes but also have impacts on socio-economic activities. Extreme high temperatures affect human well-being, cause losses of lives and reduce agricultural productivity [5].

Thus in dealing with extreme events developing countries are more vulnerable to these climatic changing patterns due to their limited adaptive capacities [6]. Water temperatures and changes in extremities of weather pattern such as droughts especially in dry and semiarid areas are projected to affect water quality, cause pollution and therefore affect the availability of food, stability, access and its consumption [7] and might have major influence on society, economy, environments and human healthiness.

In the northern hemisphere of sub-tropics most of the Arab region which covers from Maghreb in Northwest Africa to the Arabian Peninsula which is generally characterized as dry to semi-arid climate pattern with hot and dry summers and slightly winters. Arab sub-regions have different atmospheric rotation and precipitation patterns in all the regions. [8]. Economic and Social Commission for Western Asia [2010] impulses Arab states to provide more input negotiations to IPCC by preparing and demonstrating evolving international climate variation trend of their states as Arabian Peninsula (AP) shows change in sign of precipitation therefore an intensive struggle is required in the AP region to have information of climate deficit [9]. The past studies on climate change have been restricted only to North America, Europe and Australia [10] because of data availability. However, less is known about Arabian gulf (Persian gulf) precipitation and temperature trends due to high range of variability, reliability and poor data availability and quality of this region [11].

Therefore, this study aims to evaluate impact on two main climatic parameters i.e. precipitation and temperature over the neglected region of Persian Gulf i.e. Oman, UAE, Saudi Arabia, Qatar, Kuwait, Iraq, and Iran.

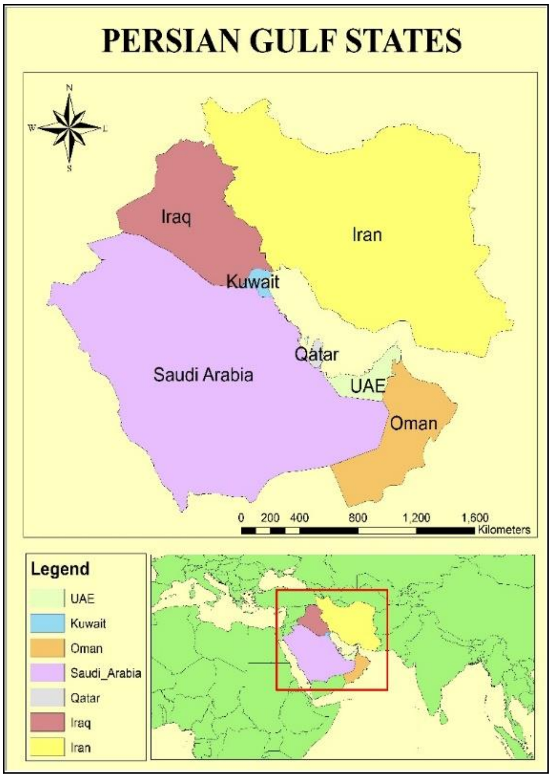
Objectives

The objectives of this study are to:

1. To analyze the expect change in climatic trends (precipitation, temperature) using ArcGIS through downscaled GCM, RCP 6.0
2. To present the spatial and temporal change using thematic mapping.

Study Area

The study area covers the countries around the coastline of Persian Gulf having coordinates 26.7505° N, 51.6834° E which is in the southwestern Asia having Oman to its eastern edge, Iran northwards, the Qatar and United Arab Emirates to South eastern edge, Saudi Arabia situated South West and Iraq along with Kuwait located North West as shown in figure 1. Its geomorphologic features include sand dunes deserts to rocky surfaces, hilly mountainous regions to flat lands, cliffs, gravel plains, coastal zones, drainage basins and alluvial soils which encompassing the huge sandy desert of the world Rub Al-Khali [12].There exists great topographical variability between these states with several contrasting climate zones, in which northern part is subtropical (north of 200 N) while southern is topical (monsoonal) type [9].



Methodology

The figure 2 presents methodology of this study. It was divided into four steps: first, data was acquired, second variables were defined, third assessment of the changing climatic trends using ArcGIS is done and finally the results of spatial and temporal change are shown using thematic mapping.

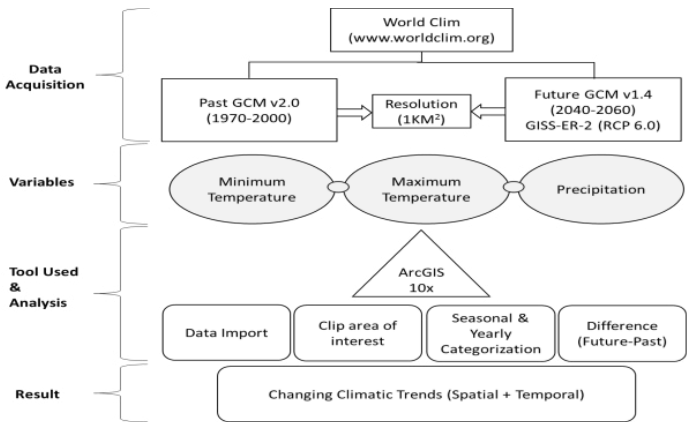


Figure 2: Methodology Flow Chart

Data Acquisition

The global rainfall and temperature downscaled gridded data for both annually and monthly, at the resolution of 1km2 at equator is downloaded from world climate organization . The worldclim database layers are generated by interpolation techniques for average monthly climate data on a 30 arc-second spatial resolution grid (referred as “1km2” resolution) which includes rainfall and maximum/minimum temperature data from 47,554 and 14,835 locations respectively for all over the world [13]. The future climate projection for the time period of 2040-2060 is derived from General Circulation Model (GCM) GISS-ER2, under Representative Concentration Pathways (RCP) 6.0. In this study, spatial and temporal variations of maximum, minimum temperature and precipitation over Persian Gulf are analyzed. The downscaled and bias corrected (calibrated) projections for the historical baseline (1970-2000) and future datasets (2040-2060) are available on worldclim website [13]. The maps with differences between the future projections and historical baseline of worldclim datasets for Persian Gulf Countries are generated which show the impact of climate changing trends in temperature and rainfall patterns.

Climate Projections In Persian Gulf

As according to published 5th assessment report of Intergovernmental Panel on Climate Change (IPCC) in 2013-14 [14], describes climate change projections during 21st century. Climate Projections are the model-driven explanators of future possible climates under a given set of changes in climatic scenarios [15].General Circulation Models (GCMs) and Regional Circulation Models (RCMs) represent tools to generate future predictions on climate changes based on different scenarios. For environmental studies, there are more than 50 GCMs available. It is the numerical illustration of climate systems based on chemical, physical and biological properties of land oceans and ice surfaces [15].Among the 50 GCMs, GISS-ER2 is selected which is developed by National Aeronautics and Space Administration (NASA) in 1960. GISS-ER2 is a useful tool in assessing the prediction regarding future climate changes as well as of atmospheric within the earth system [16]. The climate changing scenarios are referred as Representative Concentration Pathways (RCPs) and there are 4 mainly used RCPs i.e RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 which shows change in prevailing climatic scenarios. Among the four RCPs, RCP 6.0 is selected in this study, for being an intermediate emission which is neither conservative (RCP 2.6) nor extreme (RCP 8.5).

Tools Used and Analysis

For analysis ArcGIS 10x is used in this study. Initially, GCMs are imported in ArcGIS followed by extraction of area of interest. Since, GCMs represent global data, seasonal averages and differences are calculated using raster calculator. For minimum and maximum temperatures, summer, winter, and yearly averages are taken and difference between past and future climate is computed. Whereas, for precipitation monsoonal and non-monsoonal averages are taken and difference is calculated among past and future data. Finally, thematic maps are prepared illustrating spatial and temporal variations of each hydro-climatic variable.

Results And Discussions

The analysis procedure has been carried out using GISS-ER2 GCM RCP 6.0 scenario in ArcGIS which shows future prediction, past trends and difference between the future and historical changes for the maximum and minimum temperatures for summer (June, July and August), winter (December, January and February) and annually (yearly). The evaluation is done by comparison of monsoonal and non-monsoonal precipitation trend of past to the future by considering past as baseline. However, results are shown using thematic map which are comprises of three columns, the future temperature, past and the difference between the two (future and past).

Maximum and Minimum Temperature in Summer (Past And Future)

The maximum past summer temperature range of 40°C - 46°C is observed in most parts of the Persian Gulf states excluding Iran and western parts of Iraq and Saudi Arabia where the maximum temperature ranges from 34°C -40°C which is shown in figure 3. The climatic variation in Iran is of diverse nature as the northern part observes lower temperatures compared to central and southern parts, where the temperature is high. Furthermore, in future a decrease in temperature is observed in UAE and Oman ranging from 38°C -40°C compared to 40°C -46°C in the past. Whereas, in Kuwait, central part of Saudi Arabia, and Iraq will observe high temperature. Almost similar trend as in past is followed by Iran except cooling is observed in its northern part.

while in past minimum temperature range from 32.2 °C to -1.36°C is observed, Iran, Iraq and some part of Saudi Arabia shows the variation in climate patterns from moderate to high as compared to the other regions. whereas, Kuwait, Qatar and UAE experiences high minimum temperature range from 28 °C to 32 °C as shown in figure 6. However, 32 °C to -2.8 °C minimum future temperature range is evident, Iran's minimum temperature is expected to be moderate in contrast to the past temperature while Saudi Arabia observes higher temperature compared to past climate trend.

Maximum And Minimum Temperature In Winter (Past And Future)

The maximum winter temperature for past ranges from 23°C -32°C is observed in southern part of gulf states including entire UAE, Oman, Qatar and Saudi Arabia partially. Whereas, north and western part of Iran observes lowest temperature -13°C to -10°C as shown in figure 4. Moreover, almost similar trend compared to baseline is apparent in future in winter months over entire gulf state region.

On the other hand, UAE, Qatar, Oman and southern part of Saudi Arabia shows minimum temperature ranging from 27 °C - 32 °C while Kuwait, Iraq and southern part of Saudi Arabia observes moderate temperature ranging from 23 °C to 26 °C as shown in figure 7. However, Iran observes very low and low minimum temperature as compared to others Gulf Countries.

By comparing the past and future climatic trends it is observed that there is significant change in Saudi Arabia and Iraq. Saudi Arabia is under diverse temperature ranges from high and moderate to low minimum temperatures. Similarly, Iraq is likely to experience a trend shift from moderate to low temperature.

Maximum And Minimum Yearly Temperature (Past And Future)

A diversity of ranges is seen across the region in past maximum temperature. The spatial variation being, UAE, Oman and Southern parts of Saudi Arabia are under highest range of temperature 33°C -39°C. However, northern part of Saudi Arabia, Kuwait, Qatar and Iraq are seen under the blanket of moderate temperature as shown in figure 5. Whereas, lowest range of temperature looms over Iran. however, in contrast to the past an increasing trend of temperature is observed in most of the gulf states except Iran which remain cooler compared to other states.

The minimum past yearly temperature ranges from 24 °C to -10 °C is observed as shown in figure 8. Iran shows wide range of variation from 7.3°C to 18°C while Kuwait, Qatar, UAE and Oman shows the high temperature range from 17 °C to 24 °C whereas, in future there is only significant change in eastern part of Kuwait compared to its past climatic trends.

Precipitation Trends Wet And Dry Season (Past And Future)

The figure 9 and 10 shows precipitation rates for 30 years of wet and dry season for both past and future as well as difference.

The Figure 9 shows rainfall pattern during wet season (Jun-Sep) in which the northern part of Iran shows moderate rainfall ranging from 127mm -367mm in past whereas southern part of Iran, south western part of Saudi Arabia and north-south eastern part of Oman shows low rainfall ranging from 30mm-127mm. However, there is no rainfall in Iraq, Bahrain, Qatar, Kuwait, U.A.E and major part of Saudi Arabia.

While in future there will be more precipitation in northern part of Iraq and Iran ranging from 110mm-338mm of rainfall whereas middle part of Iran and Saudi Arabia will have moderate rainfall ranging from 50mm-110mm. Thus the model predicts more rainfall in overall Persian Gulf countries with less to moderate rainfall in middle part of Saudi Arabia and northern part of Iran and Iraq of the Gulf countries.

For dry season (Oct-May) figure 10 shows that there is less rainfall in the whole Persian Gulf countries in the past however north western part of Iran and north-eastern part of Iraq shows more rainfall ranging from 290mm-1042mm while in the future the model predicts less rainfall in the whole Persian Gulf countries with less to moderate rainfall in north eastern part of Iraq and north western part of Iran ranging from 116mm-312mm however some areas in northern Iran shows more rainfall ranging from 705mm-1,320mm.

Conclusion

It is concluded that the average maximum and minimum temperature in summer for past represents a diversity in region, being highest in Saudi Arabia, U.A.E and lowest in Iran. But future model predicts a decline in temperature in UAE, Oman, and northern Iran, while rise in temperature is observed in rest of the countries. Moreover, in winter overall temperature is likely to increase slightly in most of gulf states except Iran. Similarly, the yearly average maximum and minimum temperature in future is also expected to rise in almost all regions compared to the past.

On the contrary, less precipitation is recorded in Persian Gulf states except northern parts of Iraq and Iran in both monsoon and non-monsoon seasons. The trend is anticipated to continue, along with decreasing rainfall, in future time slice as per model predictions and analysis.

Therefore, the overall declining rainfall and increasing temperature act as an alarming sign for the region. It encourages policy and decision makers of each country to tackle the climate change by mitigation and adaptation measures. Moreover, it will also serve as a motivation measure for them to plan and make use of natural resources optimally to achieve the global goal of sustainable development.

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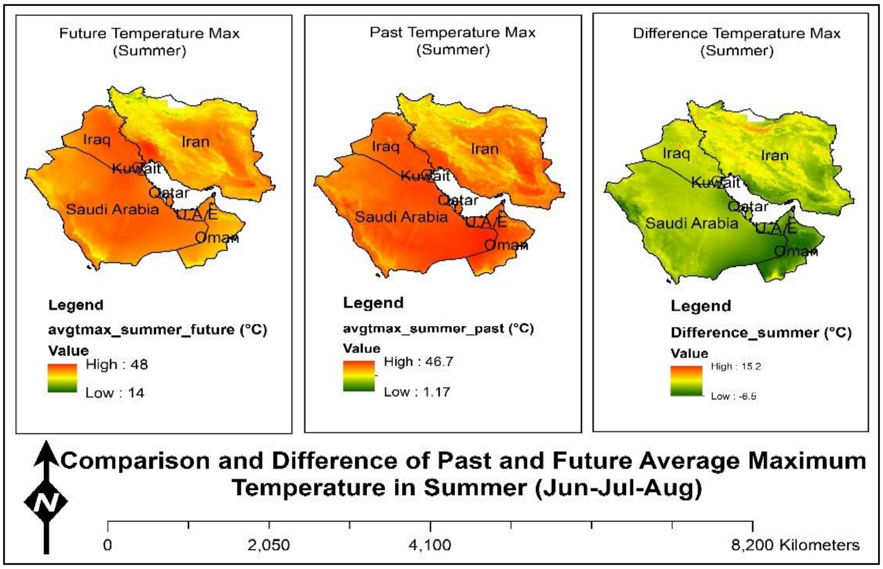

Figure 3: Past and Future Summer Maximum Temperature and Difference

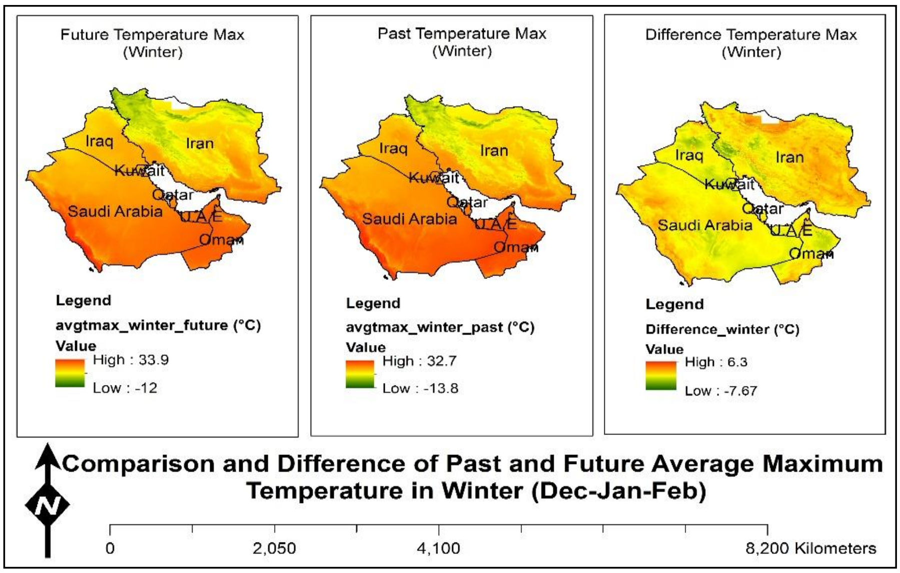

Figure 4: Past and Future Winter Maximum Temperature and Difference

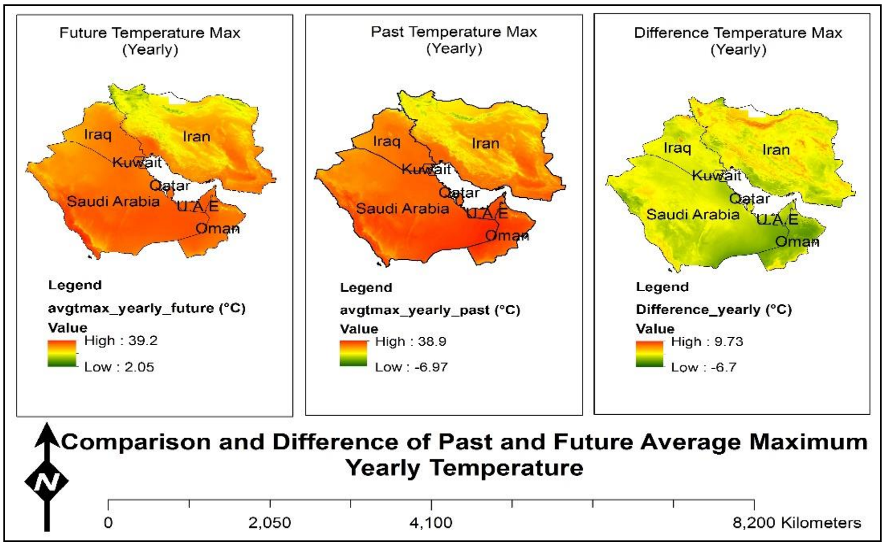

Figure 5: Past and Future Yearly Maximum Temperature and Difference

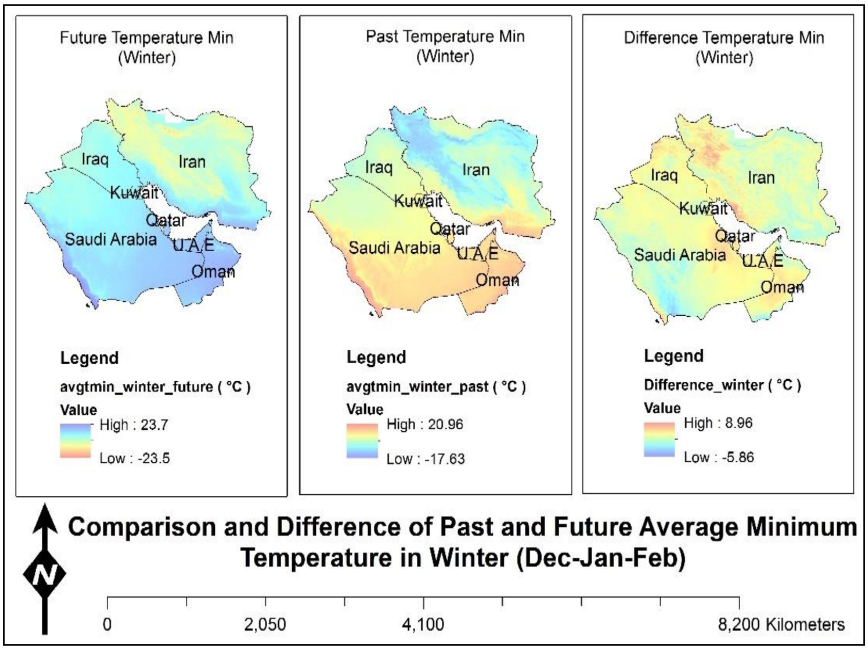

Figure 6: Past and Future Winter Minimum Temperature and Difference

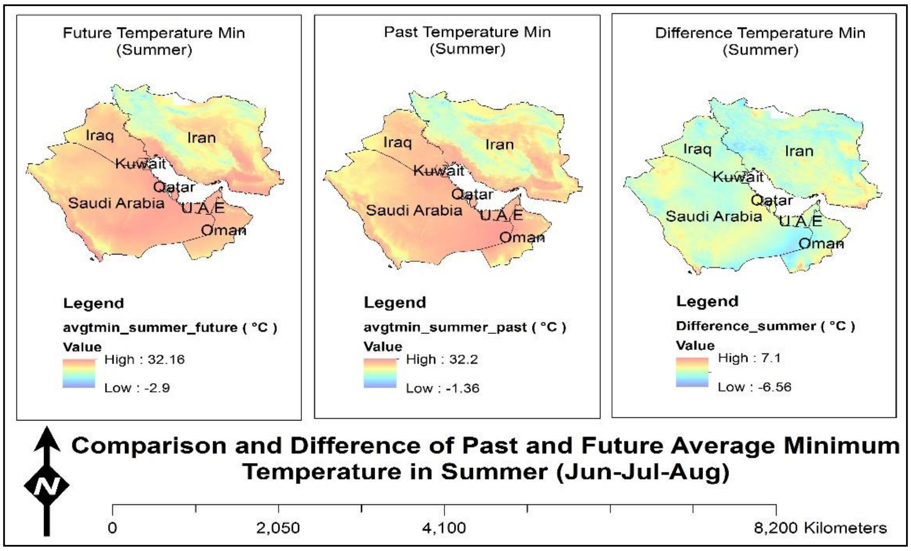

Figure 7: Past and Future Winter Minimum Temperature and Difference

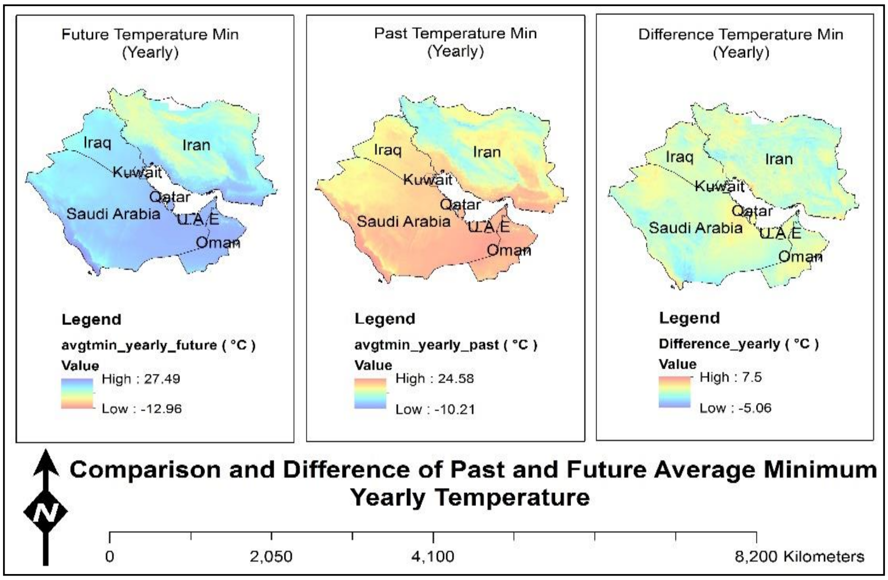

Figure 8: Past and Future Yearly Minimum Temperature and Difference

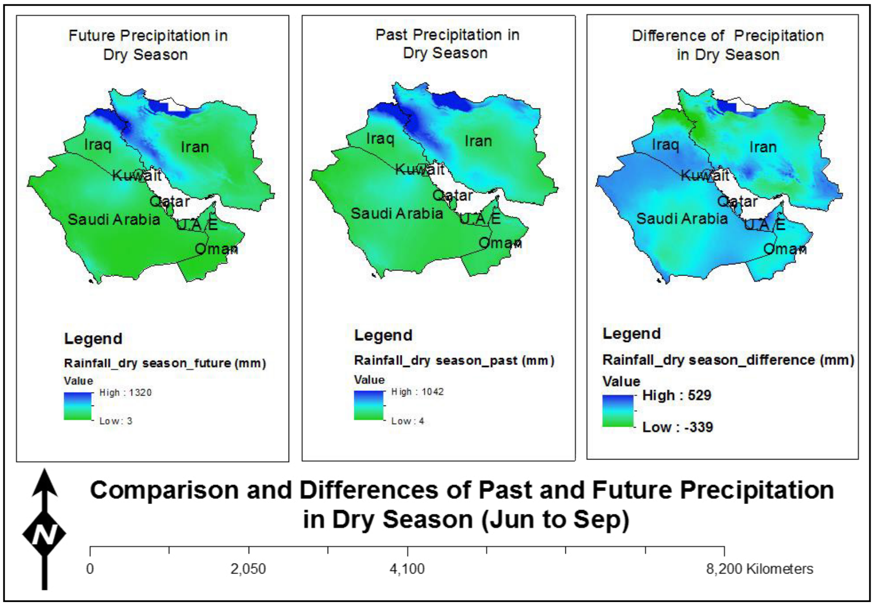

Figure 9: Past and Future Precipitation in wet season and Difference

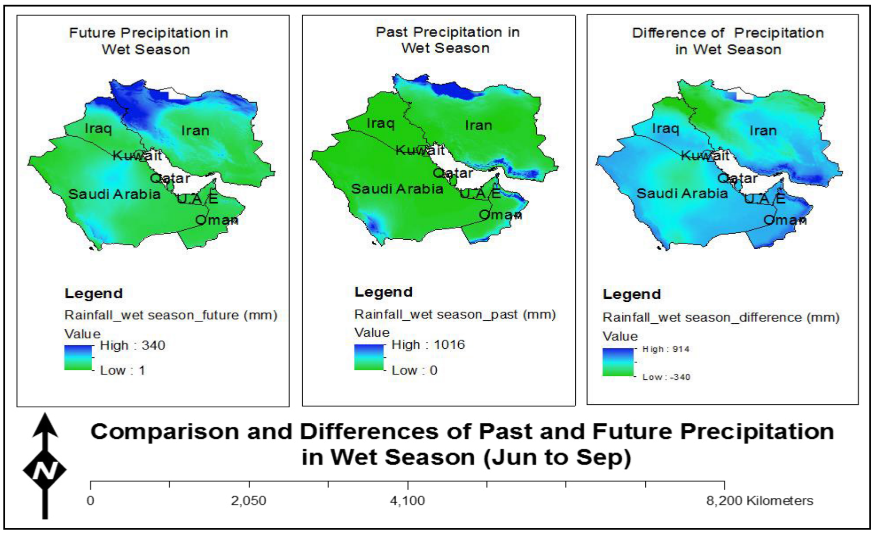

Figure 10: Past and Future Non-Monsoon Precipitation and Difference

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