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Research Article

Averting a Water War through Surface Water Management in Pakistan

"Announce to them how water must be shared among them; each will have his own special time to drink" Al-Quraan (Sura 54 The Moon, ayat 28).

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Abstract: Water is life line. Pakistan is close to becoming a water scarce country owing to our own poor water management coupled with exploitation of water resources by our neighbouring country India. If unfortunately, we become dependent on our neighbours for meeting our water requirements, they need not to wage war to enforce their dictations on us. A quantitative analysis has been carried out from extensive literature review and research studies. The paper highlights the growing water scarcity issues of Pakistan and control of water resources by India, contrary to the Indus Water Treaty. It also suggests the water management and conservation practices and sheds light on exploring new possibilities to meet our growing water demands. This study emphasizes in detail about the repercussions if we fail to realize the importance of this precious commodity and underlines importance of the needed institutional reforms. It also suggests the way forward in order to be able to meet the future challenges to avert the imminent water crisis in our country.

Keywords: Water resources, management, scarcity, issues, surface water, water economics, water reservoir, repercussions, institutional reforms

1. INTRODUCTION

The importance of water needs no explanation. It's the life line for living beings and is one of the most essential sources of existence of life. But as the world population is increasing rapidly, the water requirements are also on rise which is aggravated manifolds due to dwindling natural resources and unnecessary wastage of this invaluable source, so much so that it is now likely to threaten the peaceful co-existence of otherwise nonviolent neighbours. The water demands of the world have risen to 6 times that of its population in the last century and this thirst for water could possibly become the most significant politico-economic issue of the current century.

The conflicts for gaining control over the water resources will not be restricted to a particular part of the world, but it is likely to engulf every corner of the world ranging from the developed countries to the poorer nations. With the clock ticking, the water requirement for every nation/country on the globe is going to intensify forcing them to make necessary arrangements to meet their growing day to day water demands. The depletion of this natural resource is liable to effect the world considerably in near future and Pakistan is no exception. One of the greatest divisions in the history of mankind in the form of partition of Indian subcontinent in 1947 was also based on this fact and the interstate boundary between India and Pakistan was decided across the Indus Basin. Pakistan unfortunately became the lower riparian because of her geographical location. Despite other disputes of unfair allocation of assets and resources between the two new born states, the unjustified distribution of water resources laid the foundation of contentions between these two neighbours since their inception. These issues of distribution and utilization of water, management of these resources and construction of mega hydel power projects across the interstate boundaries are

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directly affecting these upper and lower riparian countries. It is gaining prime importance because of the scarcity and limited water availability, droughts and floods in these regions.

Pakistan's water related problems are aggravating owing to poor management of the available water resources, absolute ignorance about the importance of constructing new water reservoirs, considerable reduction of the storage capacity of the existing dams, climatic changes leading to drought conditions almost every year and the foremost being the criminal breach of the most enduring pact between two countries called the Indus Water Treaty by India. By their ambitious mega hydro-power projects like the Wular Barrage, Baglihar Dam and most recently Kishenganga Dam, India is aiming at suffocating Pakistan's economy which is heavily dependant upon agriculture, putting country's very survival at stake. Owing to her hegemonious designs, India has also been reported to aid Afghanistan for construction of two dams on Kabul River which is a tributary of river Indus. Besides dehydrating Pakistan, if India gains the control of water in this region, the strategic importance of these projects can have far reaching effects on the defense security concerns of our country.

It is high time that we start working on war footing to address this very serious issue as we are racing towards becoming a water stressed country in near future. Besides improving the water distribution and management issues, construction of new water reservoirs is the need of the hour. We also need to advocate the misplaced use of water resources by India on one pretext or the other. If we don't handle this issue technically without any legal framework, it is likely to be aggravated so much so that it could threaten a Nuclear war between the two countries. By gaining the control over this precious resource, India could easily dictate her terms in this region without waging a war. Therefore, an effort has been made through this article by highlighting the water resources available to Pakistan vis-à-vis Indian plans to construct 52 water projects [1] thereby draining most of the rivers in Pakistan paving the way for making it a water starved country like Ethiopia .

2. PAKISTAN'S SURFACE WATER RESOURCES

The surface water resources of Pakistan can be divided into three hydrological basins namely, the Indus Basin, Kharan Closed basin and the Makran coastal basin. The Indus basin covers almost 65% of the area of Pakistan and is obviously the largest basin in the country. This basin is located in two other countries besides Pakistan. About 10% of it is located in China and Indian Occupied Kashmir, each, 8% in Afghanistan and 7% in Azad Jammu and Kashmir [2]. It is spread all the way from mountainous areas of North and West to the Indus and Kacchi plains and the desert areas of Baluchistan and Sindh. The catchment area of Indus River system is 364, 700 sq miles. The major rivers in this system include Indus, Jhelum, Kabul, Chenab, Ravi, Sutlej and Beas out of which exclusive rights of the first four listed rivers rest with Pakistan. This basin contributes 141.67 MAF of water annually.

Kharan closed basin covers about 15% of the area in Pakistan stretching from northwest of Baluchistan comprising Kharan Desert and Pishin basins. 73% of this basin consists of mountainous areas. The large plateau comprises of 46,400 sq miles of arid region and the water resource potential of this area is estimated to be 0.79 MAF. The important rivers which are the prime source of water in this basin are Mashkel and Marjen, with Marjen being the minor tributary of Mashkel.

Makran coastal basin is located along the coastal belt of Baluchistan and covers 17% of the area of Pakistan. It is spread over an area of 47,300 sq miles and like Kharan basin, consists of 70% mountainous area. The principal rivers contributing water to this basin are Hub, Porali, Hingol and Dasht, which is 3 MAF annually. So, in total, around 146 MAF of surface water is annually available to Pakistan in addition to the rainfall and groundwater sources.

3. SURFACE WATER STORAGE RESERVOIRS

There are about 143 dams in Pakistan including 3 super storage reservoirs namely, Tarbela, Mangla and Chashma. Besides this, some new dams like Diamer-Bhasha dam is also in planning stages with

a live storage capacity around 6 MAF. The designed live storage capacity of Indus basin is 18.92 MAF, which includes 9.7 MAF of Tarbela, 8.51 MAF of Mangla (including new raising) and 0.71 MAF of Chashma. But due to silting, this live storage capacity has been reduced to 14.5 MAF showing a loss of almost 22% of the existing storage capacity [3]. Loss of each MAF of the storage capacity means 1MAF/year reduced water availability with a given level of reliability each year. Because of heavy siltation load from the Himalayas, our 2 main storage reservoirs are being deprived of their existing storage capacities every year. Owing to the already depleting water availability throughout the country, need for building additional storage reservoirs is becoming very important.

The extreme high and low flow characteristics of the rivers are managed by these reservoirs in order to efficiently utilize the summer surplus flows besides meeting the inter basin requirements. The total irrigation water supply requirements of Pakistan are mainly dependant upon these water storage reservoirs in addition to electric power generation. Most of the rivers flows are perennial which is primarily derived from rainfall, snow and glacial melt. Since the river flow is not consistent, water storage reservoirs are required so that surplus water can be stored for drought periods or when rainfall is very less. Unfortunately, as compared with other arid countries, the water storage capacity of Pakistan is very low. Pakistan can hardly store 30 days of water in the Indus basin which comes to about 150 m^3/capita as compared to 5000 m^3/capita for USA and Australia which is as shown in Fig. 1 [4].

4. ANNUAL WATER AVAILABILITY VIS-À-VIS DEMANDS

Absence of new storage reservoirs, climate change effects, poor water conservation practices and increasing population are leading to rapid depletion of water resources in Pakistan. We are heading towards becoming a water short country because the water availability per capita has drastically declined from 5300 m^3 to around 1000 m^3/capita per year since independence. Diversion of our river waters in sheer violation of the Indus water treaty by India is adding to this critical situation. In order to save Pakistan's economy from total collapse, which is totally dependant on agriculture, we must address this issue immediately and try to at least replenish the lost capacity with a comprehensive plan to increase our water storage capability. The data on water availability in Pakistan for 75 years is presented in Table 1 [5].

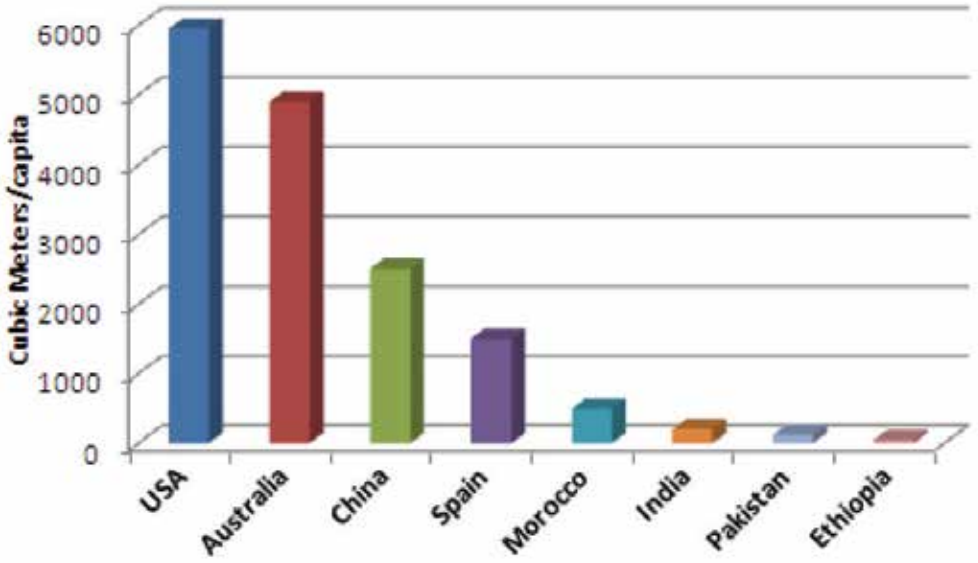

Fig. 1. Some salient countries' water availability data.

Table 1. 75-year water availability data of Pakistan.

Year	Population (million)	Water Availability (m^3)
1951	34	5300
1961	46	3950
1971	65	2700
1981	84	2100
1991	115	1600
2001	148	1200
2011	170	1050
2025	267	660

Source: UNDP Report (2005)

Water resources are the backbone of Pakistan's economy, as we are one of the world's arid countries. Our irrigation system is one of the largest contiguous irrigation systems of the world on which our agriculture system is wholly dependant. It constitutes almost 90% of our food requirements and contributes 24% of its Gross Domestic Products (GDP). Two thirds of the population living in rural areas are dependent upon agriculture which absorbs 50% of the labour force and also provides 75% of the foreign exports in terms of raw materials and other value added products [6]. This issue becomes more complex since more than 75% of water available to Pakistan is outside her territory. The use of water for agriculture is around 97% as our irrigated area has seen an increase of almost 100% in the past 50 years. The critical shortage of water is likely to endanger the food security and livelihood of our people.

5. DRAINING OF PAKISTAN'S WATER SHARE

The famous Indus Water Treaty which was hampered between the two countries in 1960 clearly defines the shares of water resources for both the countries, assigning their rights and obligations in this regard. Three western rivers (Indus, Jhelum and Chenab) were given to Pakistan while the three rivers (Ravi, Beas and Sutlej) on eastern side to India. Both the countries were given unrestricted use of the above mentioned rivers. They were put under an obligation not to stop or interfere with the flow of water in their respective rivers except for domestic and non-consumptive use. However, India was allowed limited use of western rivers for irrigation purposes. India is not only making full use of its allocated share but has also started ambitious projects like Kishenganga, Baglihar and Wular barrage on the western rivers on one pretext or the other like provision of cheap electricity to the people of Jammu and Kashmir, limited use of water for hydroelectric projects as envisaged in the treaty. The construction of these dams has serious reverberations for Pakistan in future, some of which have already been witnessed by us in recent past. The location of these structures is shown in Fig. 2 [7].

Fig. 2. Rivers flowing into Pakistan and the location of Indian hydropower projects.

5.1 Wular Barrage

India started the construction of Wular Barrage in 1985 on river Jhelum at the mouth of Wular Lake, near Sopore town in Kashmir Valley. India calls it as Tulbul Navigation Project. The maximum designed storage capacity is 0.30 MAF. India's stance on this project is to make the Jhelum river navigable during summer [8].

5.2 Kishenganga Dam

The construction on this project started in 2006, owing to the advantage taken by the Indian authorities because of unnecessary delay in the completion of Neelum-Jhelum Project by Pakistan due to budgetary constraints. It is being constructed on Kishenganga River which is called the Neelum River in Pakistan. It is designed to divert the water of this river into Wular Lake. Its live storage capacity is 0.012 MAF with power generation of 330 MW, but it will adversely affect the Neelum Jhelum Project which is just 70 km downstream of Kishenganga and reduce its hydro-power generation capacity of 969 MW by 11% incurring a loss of around $141 billion annually [9].

5.3 Baglihar Dam Project

This project is located at Chanderkot in Ramban, Southern Doda District of Indian occupied Kashmir. Construction on this project started in 1999. It has been built on River Chenab which has its origin in Indian state of Himachal Paradesh. The storage capacity of this dam is 0.16 MAF [10]. This project will deprive Pakistan of 0.32 MAF during agricultural season. India is capable of blocking the entire water of Chenab for 20-25 days.

5.4 Dams on River Indus

5.4.1 *Nimoo Bazgo Project*

It is a run of the river project constructed on River Indus about 70 kms from Leh District in Indian held Kashmir. The construction started on this project in 2005 [11].

5.4.2 *Dumkhar Hydel Power Project*

This dam is also run of the river project on Indus River located in Leh District of Indian Held Jammu and Kashmir [12].

5.4.3 *Chutak Hydroelectirc Project*

It is another run of the river power project on Suru River which is tributary of River Indus. This project is located in Kargil District of Jammu and Kashmir [13].

5.4.4 *Kargil Dam Project*

India is also constructing third largest dam of the world in Kargil district of Indian held Kashmir on the Indus River which will give her the capacity to block 45% of the water flowing into Pakistan [14].

5.5 Dams on Kabul River

The Afghan government is planning to construct at least 12 multi purpose water projects on Kabul River and its tributaries with International community's assistance. Indian experts are extending technical help to Afghanistan for building such dams with a storage capacity as high as 4.7 MAF.

6. REPERCUSSIONS FOR PAKISTAN

These ambitious Indian Hydropower projects being undertaken by India and her assistance to Afghanistan for this purpose are likely to have serious implications for Pakistan which are highlighted as under:

6.1 Agricultural Implications

As discussed above, Pakistan's economy is extensively based on agriculture. Our agriculture is wholly dependant on the irrigation system of our country. 97% use of water is allocated for this purpose. By building large and small dams, India is likely to gain significant control on our water resources with the capability to stop the water during agricultural season and also by releasing excessive water when it is otherwise not required. This will have a drastic effect on our crop production and might lead to crop failures in most parts of the country. Water availability issues will show the way to lower crop yields, downfall in live stock, shutting down of agriculture based industries. These projects will have serious implications on the irrigated areas around the Rivers and ultimately force the farmers to change their cropping patterns leading to starvation and acute food shortage and

drought through out the country.

The use of water for hydropower production is not apparently going to affect the quantity of water reaching Pakistan but the important cause of concern will be the natural timings of those flows. Interference with the timings of flows will become crucial since the irrigating areas in Pakistan will be adversely affected if the flows are not provided at the crucial timing of planting seasons. This will have far reaching negative affects on Pakistan's agricultural productions.

6.2 Economic Repercussions

Since agriculture is the life line of our economy, artificial water shortages and flooding of our lands is going to affect our economy considerably. If the water is held up during scarcity and excessive water is released during monsoon leading to vast flooding, already burdened country's economy will be stressed further because of diversion of a huge chunk of funds for tackling such issues. These problems will further aggravate thereby increasing the unemployment rates and will eventually lead to more economic dependence on other countries making Pakistan bow to unnecessary International terms.

In January 2010, 40% decline in the average flows of Chenab Rivers was observed due to construction of Baglihar dam and is going to adversely affect the irrigation system which is dependent on Chenab River. This also resulted in reduced flow at Marala Headworks during filing of this dam in 2008 and caused colossal economic losses because of scarcity of irrigation water for the paddy crops in the Marala canal command areas spread over 10,000,000 acres [15]. The diversion of water from the Neelum (Kishenganga) River will change its course and will join Jhelum River through Wular Lake in Baramulla district in Indian held Kashmir, which otherwise join each other at Domail near Muzaffarabad. Despite loss of millions of dollars annually because of around 11% loss in power generation capacity of Neelum Jhelum project, it will also threaten to render the fertile Neelum valley barren. The Wular Barrage gives India total control of waters of River Jhelum and could easily deprive Pakistan's due share in winters resulting in loss of irrigated areas downstream. This barrage also has the potential to disrupt the triple canal project of Pakistan-Upper Jhelum Canal, Upper Chenab Canal and the Lower Bari Doab Canal [16].

In 2011, India released around 100,000 cusecs of additional water in River Sutlej which her dams and storage reservoirs could not accommodate without any warning to Pakistan [16]. This resulted in flooding of dozens of villages in Kasur district inflicting loss of billions of rupees to already struggling economy of our country.

6.3 Tactical Implications

The issue of management, distribution, utilization of water resources tarnish the already feeble bilateral relations between the subcontinental states. Mega hydropower generation projects which affect the upper and lower riparian states are likely to take centre stage in defining the interstate relationships because of the water scarcity leading to droughts and floods in these states. The Indian control on the major water resources leading to Pakistan and in addition to this, her assistance for building dams on Kabul River are a serious security threat. It's a step further for Indian designs to establish her hegemony over this region. Indian ability to manage the water of River Jhelum and Chenab pose a challenge to the first line of our defence system. If the canals and tributaries originating from these rivers are dried up by blockage of water by India, our tactical maneuvers need to be revisited. Similarly, if huge quantity of water is released by India or some of her hydraulic structure malfunctions or is deliberately collapsed, it can become a disaster for our cities and villages thereby endangering our very existence. India can use these water resources to her full advantage as we are already touching the borderline of becoming a water starved country. It is quite clear from the Fig. 2, that almost all the rivers flowing into Pakistan have been capped by India, and her intentions to fund Afghanistan for the same purpose can leave Pakistan with no other option than to be dictated by Indian terms. India can achieve strategic advantage without waging a full fledge war which otherwise India couldn't accomplish after fighting three wars in last decades. If still we are oblivious of this looming threat with

a great potential of a Nuclear war and do not handle it technically without devising a thorough legal mechanism, fate of Pakistan turning into a desert cannot be averted. This will eventually be clubbed with the Kashmir issue, which Quaid-e-Azam had rightly declared as the Jugular vein of our country.

6.4 Political Aftermath

Despite of other disastrous consequences of acute water shortage, the distribution of water between our provinces has always been a hard nut to crack in which Punjab being an upper riparian is always accused of usurping the right of access to water by Sindh and Baluchistan being lower riparian. The water shortage issues will overstretch the water resources thereby creating a sense of mistrust between the federating units putting Pakistan's existence at stake.

Criminal negligence on the part of our leaders by politicizing the Kalabagh dam project which had already completed the planning phase and unpardonable delay in construction of major reservoirs including the Bhasha Dam will have long term implications for Pakistan. It is highly unfortunate that the population in irrigated areas of Southern Punjab, Sindh and Baluchistan are ignorant of the possible horrifying scenario when they will have to face severe water shortages for cultivations of the crops and possibly drinking water availability. If our leadership still use this issue for their own sinister political motives, they might take Pakistan to the verge of devastation. We will not realize the original worth of this invaluable natural resource until the well is dried up while we are busy in fighting over petty issues of inter provincial distribution of water.

7. AVERTING WATER CRISIS-WAY FORWARD

7.1 Public Awareness

First and foremost, perhaps the most important steps is to create public awareness at national level to apprise the nation about the ominous and disastrous fate awaiting us if we don't wake up and start working on war footings to address the issue which is threatening our very existence.

7.1.1 Population Explosion

There are extensive debates that the country's water availability has been reduced from 5300 cm^3 in 1950's to a mere 1000 cm^3 annually in 2012 adding Pakistan in the list of water starved countries. But the major cause of this decline in water availability is drastic increase in population vis-à-vis available water resources. This issue needs attention as the higher rates of population will squeeze the existing resources of the country whether it be water availability or access to basic amenities and resources.

7.1.2 Water Distribution among Provinces

It is the prime duties of the authorities and leaders to put the nation wise on the seriousness of the water crisis and it's the dire need of the hour to rise above our own provincial interests for the sake of our country and evolve a detailed mechanism of water distribution among the provinces which if not addressed immediately may land Pakistan in deep trouble at the wake of severe water shortages in coming future. In addition, mindset is to be changed by highlighting the advantages of the new water reservoirs putting politics aside.

7.1.3 Water Conservation

We cannot afford to waste this precious resource anymore since we are at the brink of being a water short country. The masses need to be educated about simple conservation practices which will enable us to save considerable amounts of water. This practice is being carried out in developed countries like USA despite of the fact that their water availability per capita is over 5000 cm^3 per annum but they are otherwise well aware of the value of this natural resource.

7.1.4 Changing agricultural practices.

We need to focus on latest research being carried out in agriculture. Incorporation of changes in our cropping patterns needs attention and crops requiring lesser water may be replaced by high water consuming crops. The present irrigation techniques may be replaced with new and modern practices like drip irrigation which may be investigated for implementation for improved conservation of water.

7.2 Awareness of International Community

So far we have failed to plead our case in an effective manner to the International community about the severity of water crisis in this region at the hands of India.

7.2.1 Diplomacy

Aggressive diplomatic efforts are required to bring the looming threat of a potential Nuclear war between two arch rivals into the notice of world community if this unfair thievery is not stopped by India. The latest ambitious hydro power projects being constructed or planned by India and technical assistance to Afghanistan could be used by them in choking off the Pakistan's economy turning it into a desert. This could threaten the lively hoods of our population and if not tackled at this stage could jeopardize the peace and security of the region.

7.2.2 Indus Basin Treaty

This treaty which was signed in 1960 needs revision as it was based on the flows of 1960's where water availability and demand was not a critical issue as it has become nowadays. At least respecting this treaty in true letter and spirit may be pursued and India should be stopped by taking advantage of the technical loop holes in the treaty until more effective and vibrant negotiations leading to revisions in the treaty are worked out which duly regards the rights of lower riparian. The incorporation of Water Apportionment Accord of 1991 also need to be incorporated in the amended/ or newer version of the treaty.

7.2.3 Confidence building Measures

We need to take confidence building measures with India and Afghanistan and try to establish a joint multi disciplinary fact finding group consisting of scientific and technical experts to build a mutually agreed upon hydrological knowledge base on the emerging water scenario in the region. These states should keep on exploring mutually verifiable confidence building measures in order to eradicate or at least lessen the sources of mistrust on trans-boundary water management issues. There is a need to agree on setting up of a permanent independent and separate framework or neutral expert's assessment so that policy makers of these states could follow a workable remedial course of action.

7.3 Institutional Reforms

We need to strengthen our Institutions like IRSA, WAPDA, and Irrigation Department etc. for better management of our water resources especially to devise a workable and a permanent solution of distribution of water amongst provinces. The irrigation and water sectors need to be reformed and reorganized on modern lines incorporating latest trends and research in dealing and managing water problems. Our irrigation system which is one of the largest irrigation networks of the world require revisiting so that the efficiency is increased by eliminating weak areas/sectors. We need to install the telemetry system to assess the latest situation of our rivers and reservoirs. Active collaboration with the research Institutes and Universities should be encouraged to integrate modern research with practical field application mechanism. Investment in research sector for better assessment and prediction of drought and flooding cycles is required so that the mitigation measures are taken well in time. Employing experts in the respective fields is very important because the bureaucrats may be very efficient but are comparatively incapable of fighting the case when it involves complex technicalities as it has happened in Kishenganga Dam project.

The military doctrine needs to be redefined which takes care of the affects of the Indian control of our rivers and suggest changes in our defensive and offensive maneuvers. We must appreciate the affects of sinister Indian designs of drying up of our water channels or by intentional collapse of the hydraulic structures and look for a way forward to mitigate these affects.

7.4 Exploring new possibilities

The clock is ticking and if we don't wake up now, it is going to be very late. We need to explore possible sites for construction of new reservoirs in order to store the excessive water which is being wasted annually into the sea. We need to educate the masses how the Kalabagh construction is linked to our survival as it has already completed the planning stage and a lot of financial and material

resources have gone in this project which otherwise we cannot afford to waste. Diamer Bhasha Dam and Neelum Jhelum projects need to expedited to avert Pakistan from turning into a desert.

7.4.1 *Searching Potential Sites*

Extensive research and investigations are required for exploring new catchment areas and new site for construction of water storage reservoirs making use of latest advanced research facilities like remote sensing. In this way we can investigate all those areas which were otherwise inaccessible. We can also resort to construction of small storage reservoirs at local, regional or provincial level depending upon the land availability.

7.4.2 *Capping the Hill Torrents*

We have already exhausted our existing water storage capacity and our water resources. A rigorous and dedicated effort is required in order to explore and develop the resources of water in the form of hill torrents. It is not an easy task because of large fluctuations in the peak and normal flows, large sediment flows and its timings which might not be in consonance with our cropping pattern. Moreover, hill torrents involve high velocity flows which result in erosion. But there is a vast potential of capping this water resource by incorporating elaborate investigation and research in this field.

7.4.3 *Funding Options*

Since Pakistan's economy is already going through turmoil, we need to find out foreign funding options. It is only by effective investigations that we can convince funding agencies like World Bank and United Nations if we highlight this serious disaster which is awaiting us. We need to enhance the diplomatic efforts for persuading the International community the dire need of water resources construction projects.

8. CONCLUSIONS

It is high time that we open our eyes and start working on war footing to avert this looming water crisis which is in the offing for our nation the near future. If we do not employ a multi faceted approach to address this issue and take immediate steps simultaneously at various different fronts, a very gloomy fate is awaiting us rendering a fertile Pakistan into a barren desert like Ethiopia and Somalia. Our coming generations will not forgive us on this criminal negligence if waste this naturally gifted land full of resources. We need to take immediate remedial measures to avert the ominous Indian designs of choking our water resources by taking care of each and every drop of this invaluable resource of water.

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Research Article

Sustainable and Optimized Utilization of Water Resources: Inflatable Dams Potential in Pakistan

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Abstract: Development of new reservoirs are utmost important for their utilization of providing water for irrigation, hydropower and flood damages reduction etc. In-addition to constructing new reservoirs, the efficient and sustainable use of existing reservoirs is also important for rapid economic growth of world. Pakistan is blessed with rich surface water resources of 180 Billion m^3 annualy. However, total storage capacity of the three large dams is 17 Billion m^3 which is only 10% of the available water resources. The current study identifies the latest trends for optimizing the utilization of water from reservoir to agriculture farm and their possible application to Pakistan. The paper also investigates the potential of inflatable dams in Pakistan for recharging of groundwater, as diversion weir for small hydropower plants, water supply and creating artificial lakes for recreation purposes. On the basis of criteria developed in the study, 31 sites were selected for checking their feasibility. SRTM 90m digital elevation database and Google Mapper were used to develop digital elevation models and contours for studying different technical parameters. Total 27 sites were found feasible and indicated the potential for Inflatable Dams in Pakistan on the basis of preliminary results. For sustainable and optimized utilization of water resources, it is utmost important to implement the following measures identified for supplying water from reservoir to crop root zone are: remodeling/ modernization of barrages and canals including lining of distributaries and minors. Adoption of resource conservation technologies, and optimized cropping systems by including high value and high yield crops are recommended in the study for achieving the desired objectives.

Key Words: Water resources, Pakistan, inflatable dams, reservoirs operation, sedimentation, Tarbela, Diamer Basha

1. INTRODUCTION

Reservoirs play a vital role for rapid economic growth all over the world by providing water for irrigation, hydropower and reducing floods. During 20th century, the focus was only towards developing new reservoirs. However, now approach is shifted to preserve existing reservoirs as well as developing new reservoirs. Total 33,100 dams have been constructed worldwide whose total storage capacity is more than 6900 km^3 upto 2010. The worldwide development of new reservoirs is depicted in Fig 1. [1, 2].

Globally, the rate of reservoir sedimentation is about 0.1-2.3% annually with yearly average storage loss of about 1.0 % [3]. Due to sedimentation, estimated value of loss is approximately 9 billion US dollar per year. China is suffering from highest average annual storage loss, while the lowest average annual loss of storage has been observed in North Africa [3].

The current study emphasis the sustainable utilizes of water resources by developing new reservoirs and identifies the latest trends/measures for optimizing the utilization of water from reservoir to agriculture farm and their possible application to

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Pakistan. Moreover, it investigates the feasibility and potential of inflatable Rubber Dams in Pakistan.

1.1 Importance of Reservoirs

Sediment deposition is the major cause of loss of reservoirs' capacities constructed during 20th century, which had already been built on the most captivating sites worldwide. On the other hand, many reservoirs are not providing optimized payback. The reason of lesser payback is that these reservoirs are not operating on the concept of optimization. The possible benefits are hydropower, irrigation, storage conservation and control of damages due to flood.

The demand of construction of reservoirs is increasing with growing population of the globe. The reservoirs and dams are helpful in serving mankind by production of food, fiber, hydro power and economic growth. About 30-40% of 268 million hectare land of the world is cultivated by 45,000 large dams. About 12 – 16 % of the world's food production is associated with reservoirs with significant global energy supply [1].

Many countries around the world have developed significant reservoirs for storage of available surface water resources in the river basin. Table 1 shows the %age storage developed in different river basin in the world. Pakistan has minimum %age storage from available water resources amongst the river basins compared in Table 1. It is, therefore, utmost important to develop new reservoirs. The existing storage capacity of the reservoirs of Pakistan has been provided in Table 2 [4].

1.2 Optimized Operation of Multiple Reservoirs

World Commission on Dams [2] reported that there is still great potential available to get more benefits from the existing reservoirs as they are not being operated on the principle of optimized benefits. Preferably, the design and operation of reservoirs should be such that to maximize net benefits which can be achieved by using various optimization methods. The optimization methods includes genetic algorithm, linear and dynamic programming which are also in practice in reservoir research studies. Genetic algorithm is a popular optimization method based on principles of mechanics of natural

Table 1. River Basins and developed storage reservoirs [8].

River basin	Average annual flow (MAF)	No. of dams	Live storage capacity (MAF)	%age storage
Colorado	12	3	59.62	497
Nile	47	1	132	281
Sutlej Beas (India)	32	5	11.32	35
Yellow River	345	7	68.95	20
Pakistan Indus System	145	3	14.06	10*
World Average	**20,000**	**-**	**8,000**	**40**

Table 2. Reducing Storage Capacity due to Reservoir Sedimentation [8].

Reservoir	Live Storage Capacity (MAF)		Storage Loss (MAF)
	Original	Year 2014	Year 2014
Tarbela	9.69 (1974)	6.4	3.29 (34%)
Mangla	5.86(1967) +2.88*(2012)= 7.48	7.4	0.85 (10%)
Chashma	0.72 (1971)	0.26	0.46 (64%)
Total	**16.27**	**14.06**	**1.60(26%)**

***** 2.88 MAF storage was added in 2012 due to Mangla raising

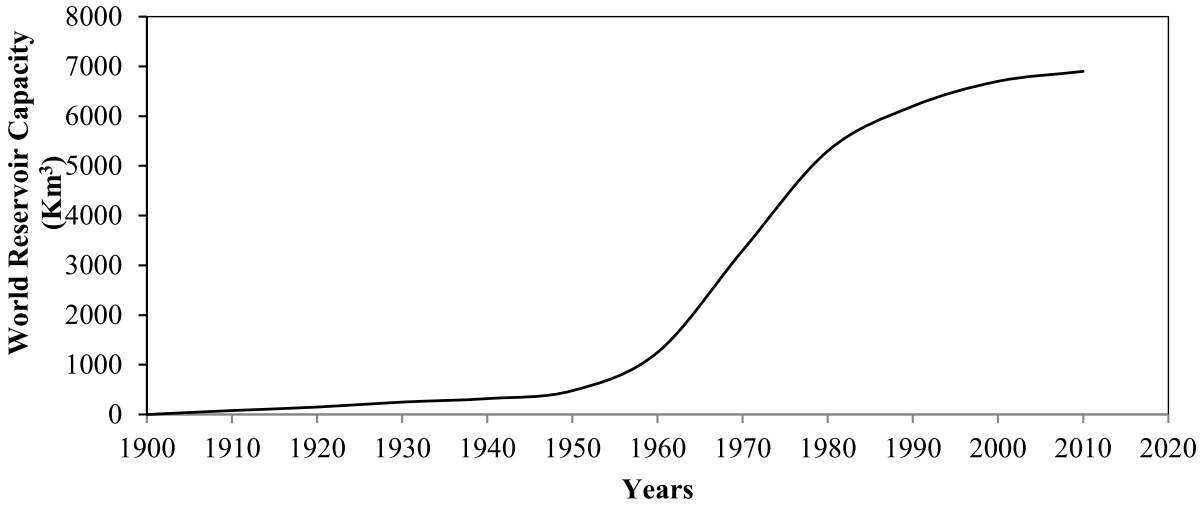

Fig. 1. Development of World Wide Reservoirs [1].

science and selection. This method is suitable for multi task characterization and many advantages to other methods [5-8].

To characterize the rule curve of reservoirs for multiple reservoirs operations Chen and Chang formulated hyper cubic distributed genetic algorithm (HDGA) [9]. However they neglected the sediment evacuation effect for optimization. Suiadee and Tingsanchali worked on Nam Oon reservoir, Thailand and produced combined simulation genetic algorithm (GA) model to evaluate optimum operational rule curves. The powerful and robust proposed model was combination of simplicity and simulation techniques [10]. To optimize the rule curve of Tapu Reservoir in Taiwan, a flushing model was prepared. The flushing model was a combination of simulation and sediment evacuation based on genetic algorithm optimization concept [11]. The model ROSSE i.e. Reservoir optimization-simulation with sediment evacuation was developed for Tarbela dam located in Pakistan. The GA based model helped to optimize the rule curves [12].

To forfeit the energy crises of Pakistan and to improve the irrigation system, optimized operation of multiple reservoirs on Indus Basin is mandatory. Currently the researchers are more focussed on design and operation of individual reservoirs than multiple reservoirs. Whereas, there is urgent need to derive the method of optimization for multiple reservoirs in order to improve the storage conservation, irrigation system, power generation and to reduce the flood damages.

The optimized hydropower, irrigation, storage and flood damages reduction benefits of reservoirs in Indus Basin, Pakistan are summarized in Table 3. Rashid et al. [13] revealed that objective-function for irrigation, hydropower and storage conservation benefits will be improved by 13%, 11% and 84% whereas flood damages will decrease by 75%. The results also indicated enhancement of benefits upto US$ 960, 579, 533 and 649 M annually for all the four components. It is evident from the Table 3 that by optimized operation of multiple reservoirs operation by considering sediment evacuation of multiple reservoirs, the benefits will be enhanced by about 49%.

1.3 Inflatable Rubber Dams

Inflatable dam consisting of a sealed inflatable rubber coated fabric tube anchored to a concrete foundation constructed across a river (Fig. 2). Inflation is introduced by use of air or water or both. When fully inflated the inflation acts like impound to water and behaves like other fixed dam. The particular feature of inflated dams is the quick deflation for preventing floods. Deflation occurs automatically as the backwater reaches a certain level. In developed nations like United States, use of inflatable dams is increasing rapidly and over 200 inflatable dams have been installed since 1980. Table 4 summaries the worldwide use of inflatable dams [14-16].

The concept of inflatable dam is relatively new in South Asia. However, it had been used to large extent in Australia, China and Scandinavia

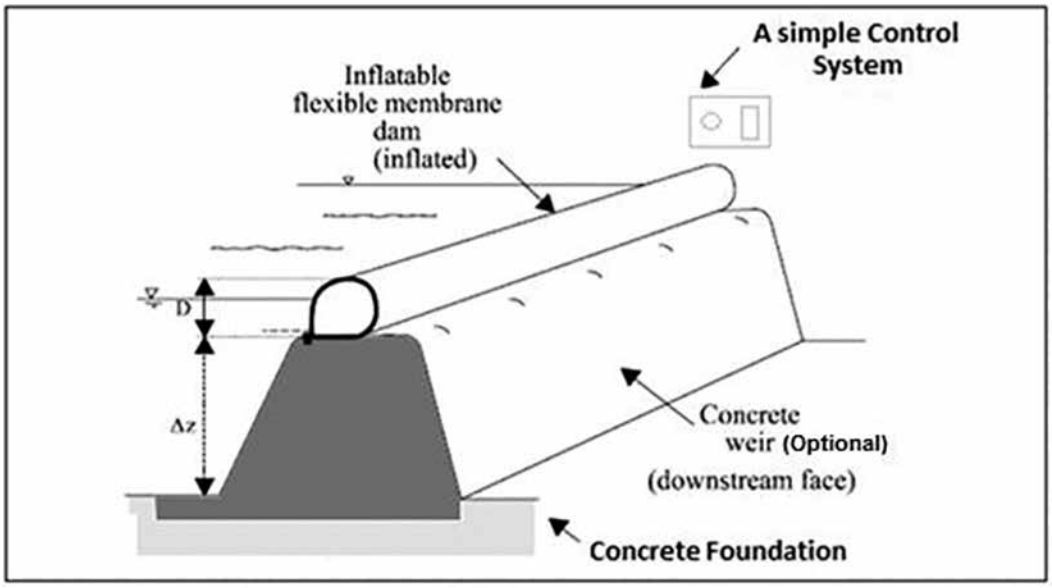

Fig. 2. Schematic view of inflatable Rubber Dam.

countries. Rubber dams have added advantage of simple and short period of construction. Moreover, these dams have shown good performance in seismic areas [17]. Rubber Dams have been used since last 60 years for river and coastal engineering applications. The use of water stored in rubber dams for irrigation purposes is most recent practice adopted in Australia. Chansen [18] developed new method for predicting the overflow characteristics and guidelines suggesting optimum location of deflector in the rubber dams. Discharge calculations and analysis are of great importance and necessary for good operation and sediment controlling of cascade rubber dams. The

Table 3. Enhanced benefits due to optimized operation of multiple reservoirs.

Sr. No.	Reference	Case Study Reservoirs	Total Optimized Benefits (Million $/year)	Increase in Benefits w.r.t. existing rule curves (Million $/year)	% Enhanced optimized value
1	Khan et.al (2009)	1. Tarblea	1147	82	42%
2	Rashid et al. (2015)	1. Tarbela 2. Diamer Basha	2988	977	49%

Table 4. Summary of Inflatable Dams World Wide [15-16].

Country	Year Introduced	Type of inflation	Number of Dams Installed
France	1972	Water	25
Austria	1977	Water	60
Japan	1978	Air or Water	> 700
Germany	1984	Air or Water	40
USA	1988	Air & Water	111
Australia	1997	Air or Water	3
Czech Republic	1980	Water	20

principles of water balance and weir flow are the basis of fall discharge and maximum discharge of cascade rubber dams [19]**.** The long term (35 years) investigation of construction, operation, management and maintenance of a rubber dam of 20 dams in Hong Kong concluded that rubber dam had been successfully used for many different purposes such as irrigation, flood control, environmental improvement and water supply [20].

Hassan and Kabir [21] studied the appropriateness and consequence of rubber dam on agriculture in Bangladesh. The outcomes were evaluated in three categories i.e. hydraulics, agriculture and socioeconomic. The results indicated the agriculture performance adequate. Socio economic conditions depicted its financial viability in terms of profitability. The rubber dam was found hydraulically safe with high probability of water availability. Finally, the results revealed great affect on national economics of the country along with its suitability for recharging ground water.

Rubber dams have been considered successful to lower the flood damages and irrigation purposes in Hong kong. Moreover, due to versatility of different benefits, Rubber dams were recommended multipurpose dams [22]. Inflatable Flexible Membrane Dams (IFMD) had been used for many years in developing and developed countries as a flexible weir for inflatable dams. Latest computations were derived specifying wall pressure distribution for overflow conditions and hazards [23].

Yadav [24] elaborated the benefits of rubber dams as simple hydraulic structure, easy to operate, high seismic resistivity, low construction cost, minimum affects on ecology and environment, very useful for water management of urban areas, high construction feasibility and its effectiveness to cater high variation of low and high flows and tides. Sarker et al . [25] discussed the performance of rubber dam on irrigation improvement in South Asian Region by evaluating the parameters i.e., Command Area Efficiency (CAE), Management Performance Ratio (MPR), Yield Efficiency (YF) and Benefit Cost Ratio (BCR). On the basis of results obtained, 63.9% CAE, 0.028 MPR, 41.8 kg/m^3 YF and 1.34 BCR, it was concluded that the overall irrigation performance and agriculture outputs had been enhanced. Some constraints were also identified in the study as lack of stake holders and farmers participation.

The inflatable and deflating characteristics are great advantage of rubber dam as when water need to be store so the dam is inflated and when the chances of flood risk increases the dam is deflated. Silt deposits, debris and garbage can be evacuated by deflating the dam. Ceramic chips coating and stainless steel mesh have been used for inflatable dams for improving the flexible membrane [26].

2. DESIGN CRITERIA FOR SELECTING THE SUITABLE SITES IN PAKISTAN

The design criteria defined for the selection of potential dam sites are as follows:

- It is evident from literature review that most of existing inflatable dams in the world and in China are located downstream of the bridges. Similarly, for exploring the inflatable dam sites in Pakistan, the location of bridges on Ravi, Sutlej and Jhelum have been given preference for preliminary studies. Other sites on rivers in plain areas have also been explored in the study.
- Those areas where groundwater is depleting are given preference.
- The areas lying in sweat groundwater zone has given preference.
- Massive Resettlement should not be involved due to reservoir.
- Geotechnical and geological ground conditions should favour the construction of dam.
- Negative impact on installations i.e. railway bridge etc. should not be affected due to reservoir.
- The areas near cities have given importance.

3. SHUTTLE RADAR TOPOGRAPHY MISSION (SRTM) DIGITAL ELEVATION DATA

SRTM was internationally established in 1960 for obtaining digital elevation models and high resolution digital topographic database and images of world. The 30 m (one arc second) resolution of the raw data was only available for United States initially. However, in November 2011, similar

resolution limited featured data was released for Australia and for remaining world only 90 m Digital Elevation Data (DED) has been provided [27] . STRTM 90 m (3 arc second) DED has been used in the study because of its added advantages i.e., It is freely available worldwide and has best quality. Its results are considered reliable all over the world. It has been successfully utilizes for developing Digital Elevation Models (DEM) of sites all around the world. SRTM has limitation that its DED is only available at 90 m resolution. However, 90 m DED is workable for present study because all the proposed sites considered for Inflatable rubber dams lies on plain area of Punjab Province having mild slopes and objective of the study is to find out the potential of inflatable rubber dams in Pakistan. The comparison of SRTM data base was done with high resolution Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) and concluded that the results were compatible with each other [28].

4. TECHNICAL ANALYSIS FOR PROPOSED DAM SITES

The tentative locations were identified as per developed design criteria using Google Earth software. 31 selected sites for checking their suitability are shown in Table 5. The location of selected sites has also shown in Fig. 3. The sites have been donated by respective ID. Nos. as mentioned in Table 5.

Table 5. Proposed sites of Inflatable Dams in Pakistan taken in the study for checking their suitability.

ID. No.	Description of Dam	River
1	Victoria Bridge	Jhelum
2	Lahore Islamabad Motorway Bridge	Jhelum
3	Khushab bridge	Jhelum
4	Jhelum bridge on GT road	Jhelum
5	Head Muhammad-wala bridge near Multan Byepass on Khushab road	Chenab
6	Muzaffargarh Chenab bridge near Muzaffargarh road Multan	Chenab
7	Okara Faisalabad road bridge	Ravi
8	KhanewalKabirwala road bridge	Ravi
9	Toba Chichawatni road bridge	Ravi
10	Road bridge on river Sutlej near Pakpattan	Sutlej
11	Road bridge on river Sutlej near Mailsi Syphon	Sutlej
12	Site near road bridge (N5) on river Sutlej near Bahawalpur	Sutlej
13	Musa Shaheed bridge on river Sutlej at Jalalpur Road	Sutlej
14	Bridge on Arifwala Sahiwal road near Bahawalnagar	Sutlej
15	Ravi River near Baghdad Sharif	Ravi
16	Ravi River at Kamalia Harappa Road	Ravi
17	Satluj River near Kanganpur	Sutlej
18	Satluj River near Mandi Ahmad Abad	Sutlej
19	Chenab River near KotKhaira	Chenab
20	Chanb River near JalalpurBhattian	Chenab
21	Satluj River near Fatehpur	Sutlej
22	Chenab River near Bhawana	Ravi
23	Ravi River near Sayedwala	Chenab
24	Chenab River near Khangarh	Jhelum
25	Jhelum River near Kurpalka	Chenab
26	Chenab River near Chowk Permit	Jhelum
27	Jhelum River near Jhawarian	Jhelum
28	Chenab River near Garh Maharaja	Chenab
29	Jhelum River near Mohibpur	Jhelum
30	Chenab River near Qadirabad	Chenab
31	Jhelum River near Tetri	Jhelum

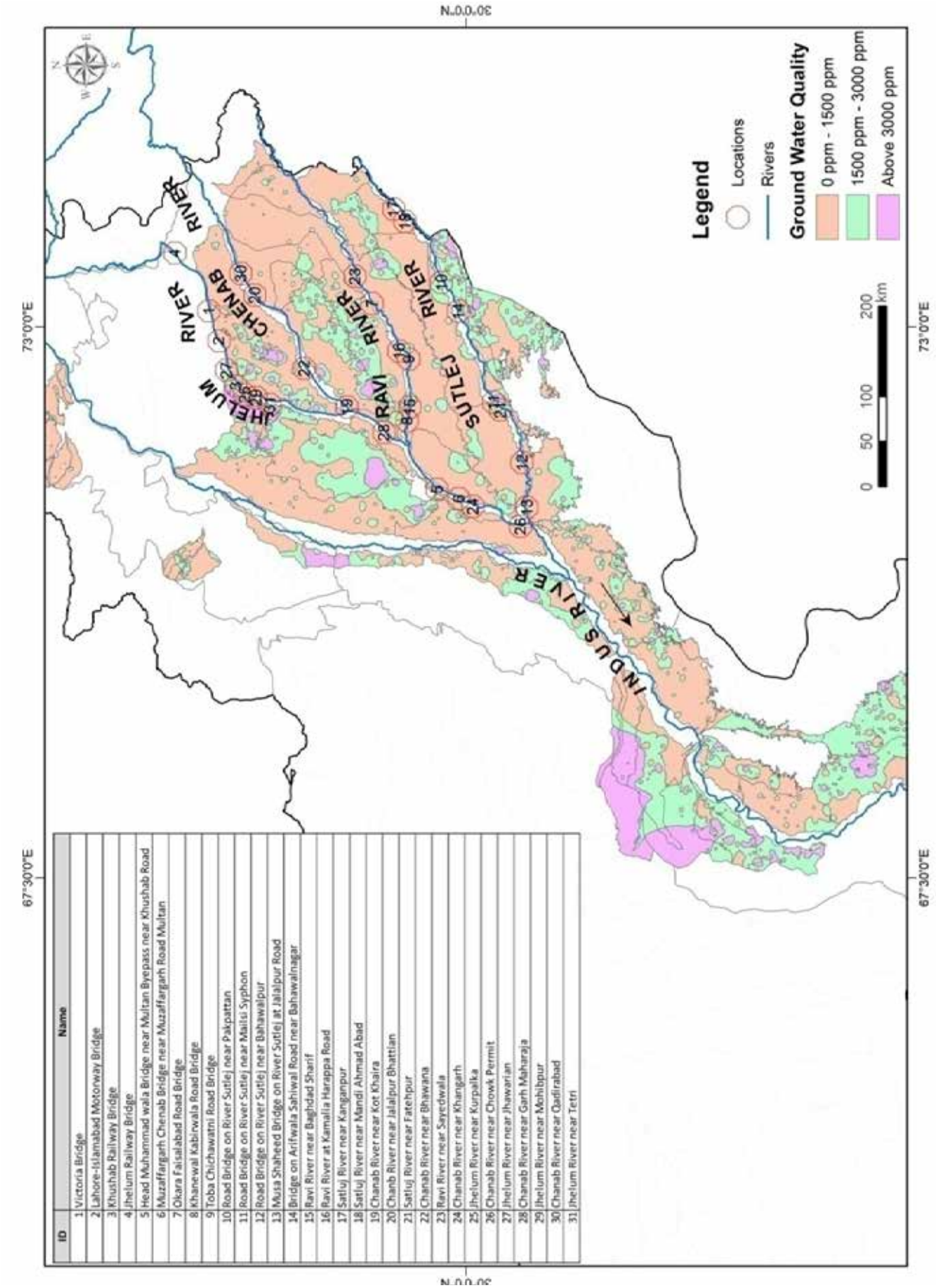

Fig. 3. Location of Inflatable Dams in Pakistan along with the Groundwater quality.

Water quality maps developed using 2012 groundwater data have been used to analyze the groundwater quality at the proposed locations. As per design criteria, the proposed sites must be located in sweat water zone and the groundwater shows the trend of depletion. The groundwater quality map at the proposed dam locations is shown as Fig. 3. The groundwater quality has been graded in three ranges on the basis of total dissolved solids (TDS) as presented in Table 6. The groundwater quality at the proposed location is generally good, as the inflatable dams are located on rivers. However, two sites on Sutlej River at Fatehpur and Mailsi siphon bridge were observed in Bad groundwater zone having TDS quantity greater than 3000 ppm and were discarded from the list of selected sites. SRTM 90 m Digital Elevation database has been used to develop Digital elevation models (DEM) of all the selected sites. Google Mapper is then used to resample the data and to generate 3 m contours at the proposed dam sites for different heights. The pond area has been accessed at different dam heights. The selection of final dam height and pond area is subject to different parameters i.e. public buildings and installments, resettlement of people, sufficient availability of pond etc. Moreover, after analyzing different sites it has been observed that 3 m dam height is considered suitable for finding the reservoir area and capacity. It has been analyzed that the sufficient pond area and capacity of two dams at Muzaffargarh Chanab Bridge near Muzaffargarh Multan on Chanab river (ID. No. 6) and Musa Shaheed bridge on river Sutlej at Jalalpur Road (ID. No. 13) were not available. These two locations are not considered feasible for constructing inflatable dams. The pond area of sites from ID. No. 15 to 31 have been computed by taking the general slope of rivers in plain areas of Punjab i.e. 1in 4000.

Table 6. Range to grade groundwater quality**.**

Sr. No.	Range of Total Dissolved Solids in PPM	Quality
1	0-1500	Good
2	1500-3000	Marginal
3	>3000	Bad

The exact capacity of reservoirs can only be determined by conducting Bathymetric survey. The bathymetric survey of all the sites is not available. Hence, the approximate capacity of those sites whose bathymetric survey is not available has determined using the criteria as follows:

Capacity of reservoir = average height of dam x pond area.

5. RESULTS REGARDING PRELIMINARY ASSESSMENT OF SUITABLE PROPOSED SITES INFLATABLE DAMS IN PUNJAB, PAKISTAN

On the basis of technical analysis, the results have been formulated in terms of groundwater quality, dam height, dam length, reservoir area and reservoir capacity to predict the feasibility of

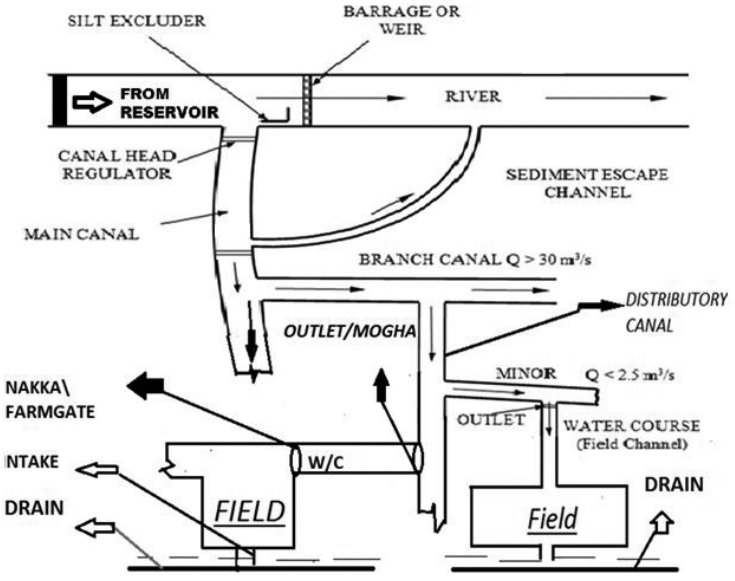

Fig. 4. Schematic Diagram of Typical Irrigation system of Pakistan

Table 7. Summary of results regarding preliminary assessment of suitable proposed sites Inflatable Dams in Pakistan.

Sr. No.	ID. No.	Description / Location of Dam	River	GroundWater Quality	Dam Height m	Dam Length m	Reservoir Area Million m^2	Reservoir Capacity Million m^3
1	1	Victoria Bridge	Jhelum	Good	3	856	5.1	7.65
2	2	Lahore Islamabad Motorway Bridge	Jhelum	Good	3	868	5	7.5
3	3	Khushab bridge	Jhelum	Good	3	716	10	15
4	4	Jhelum bridge on GT road	Jhelum	Good	3	1064	4.3	6.45
5	5	Head Muhammad-wala bridge near Multan Byepass on Khushab road	Chenab	Good	3	600	6.5	9.75
6	7	Okara Faisalabad road bridge	Ravi	Good	3	791	9.4	14.1
7	8	Khanewal Kabirwala road bridge	Ravi	Good	3	121	1.5	2.25
8	9	Toba Chichawatni road bridge	Ravi	Good	3	417	6.4	9.6
9	11	Road bridge on river Sutlej near Mailsi Syphon	Sutlej	Moderate	3	585	7.02	10.53
10	12	Site near road bridge (N5) on river Sutlej near Bahawalpur	Sutlej	Good	3	652	1.68	2.52
11	14	Bridge on ArifwalaSahiwal road near Bahawalnagar	Sutlej	Good	3	634	7.602	11.403
12	15	Ravi River near Baghdad Sharif	Ravi	Good	3	246	2.952	4.428
13	16	Ravi River at Kamalia Harappa Road	Ravi	Good	3	709	8.508	12.762
14	17	Satluj River near Kanganpur	Sutlej	Good	3	240	2.88	4.32
15	18	Satluj River near Mandi Ahmad Abad	Sutlej	Good	3	458	5.496	8.244
16	19	Chenab River near KotKhaira	Chenab	Good	3	718	8.616	12.924
17	20	Chanb River near JalalpurBhattian	Chenab	Good	3	1531	18.372	27.558
18	22	Chenab River near Bhawana	Ravi	Good	3	980	11.76	17.64
19	23	Ravi River near Sayedwala	Chenab	Good	3	1173	14.076	21.114
20	24	Chenab River near Khangarh	Jhelum	Good	3	875	10.5	15.75
21	25	Jhelum River near Kurpalka	Chenab	Good	3	1158	13.896	20.844
22	26	Chenab River near Chowk Permit	Jhelum	Good	3	790	9.48	14.22
23	27	Jhelum River near Jhawarian	Jhelum	Good	3	1003	12.036	18.054
24	28	Chenab River near Garh Maharaja	Chenab	Good	3	1114	13.368	20.052
25	29	Jhelum River near Mohibpur	Jhelum	Good	3	559	6.708	10.062
26	30	Chenab River near Qadirabad	Chenab	Good	3	1344	16.128	24.192
27	31	Jhelum River near Tetri	Jhelum	Moderate	3	381	4.572	6.858

proposed selected sites. The results are shown in Table 7. It was revealed that 27 sites out of 31 sites were considered suitable for constructing inflatable rubber on the basis for preliminary study which indicates the potential of Inflatable Rubber Dams in Punjab and Pakistan.

The typical diagram of irrigation system from the reservoirs to the agriculture filed is shown in Fig. 4. The latest trends identified for optimized utilization of water from reservoirs to agriculture farm have been elaborated in the following section.

6. IRRIGATION SYSTEM MANAGEMENT

Food and Agriculture Organization (FAO) [29] discussed that detailed diagnosis including the performance, present condition, original design and other deficiencies are very important for remodeling and modernization of any irrigation system. The important parameter for remodeling of irrigation channels is change in concept, structure and design. It considers modification in technology, techniques and future consideration of future needs of operation and maintenance [30].

FAO [31] presented detailed methodology for modernization of irrigation canal systems for improving performance. The strategy was developed for analyzing channel optimization on the basis of Mapping System and Services for Canal Operation Techniques (MASSCOTE). During the process of remodeling and modernization, the expectations and achievements had to be kept at realistic and practical level. The most economical and easy-to-implement options were selected to start the process of modernization. Fig. 5 depicts road map for enhancing irrigation water management at canal command level.

The structural measures identified in the present study for improving canal management and conveyance efficiency of canal system

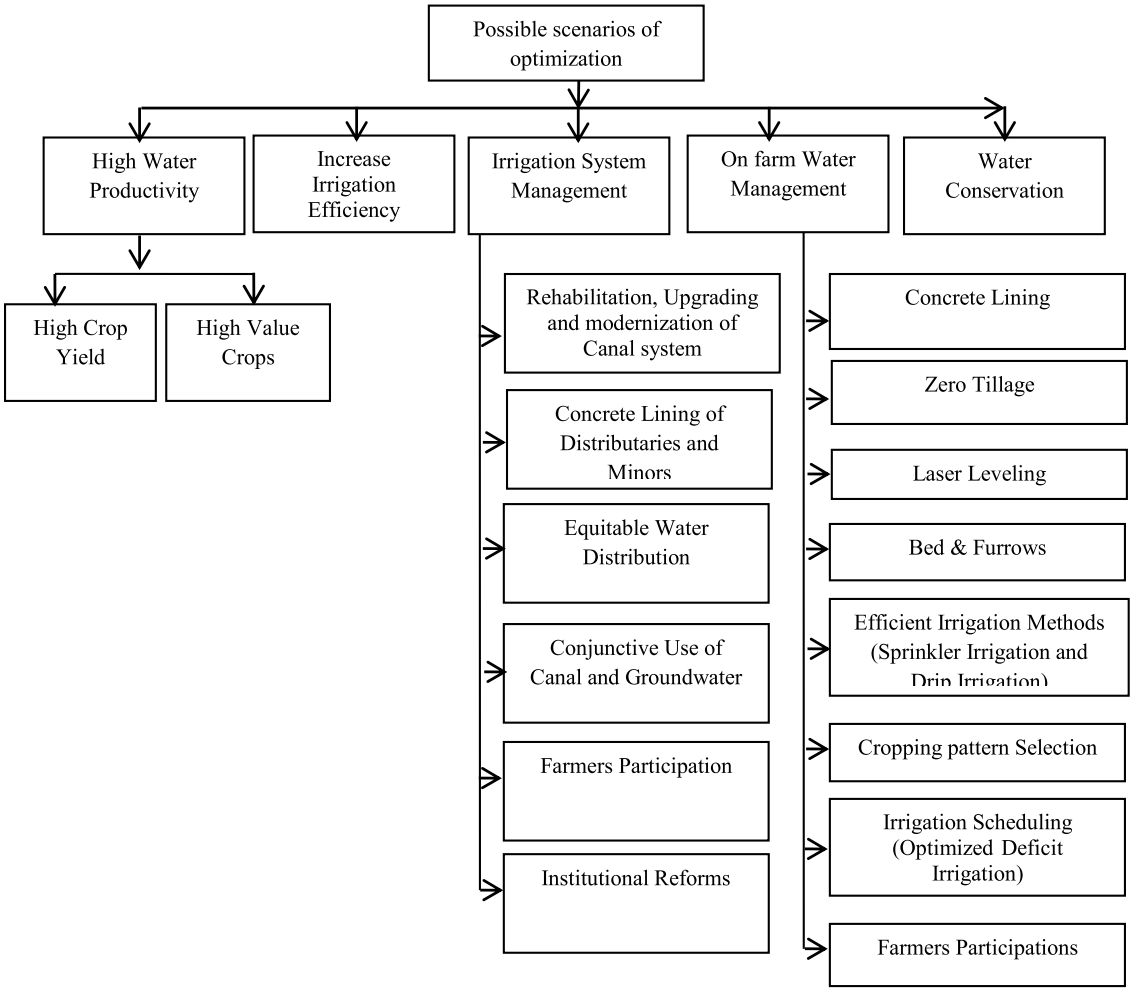

Fig. 5. Schematic Diagram of Optimization of irrigation water management at canal command level.

includes; rationalization of canal capacities in keeping with the current water requirements and availability, rehabilitation and remodeling of canal network and lining of distributaries and minors in saline groundwater areas. The rehabilitation and remodeling of canal involves improving the channel prism to cater for enhanced discharge, raising and strengthening of canal banks, providing cattle ghats, upgrading hydraulic structures had been suggested. Suggested water management measures are regular water flow measurements to ensure adequate, reliable and equitable water distribution at different levels of irrigation system and participation of farmers in the operation and maintenance of canal system using the ongoing reforms framework, whereby the farmers are being empowered for management of the distribution network.

7. ON-FARM WATER MANAGEMENT

An array of measures and practices for improved water management at the farm level includes: improvement and lining of watercourses, proper farm design and layout, adoption of resource conservation technologies involving laser land leveling, zero tillage, and bed-furrow irrigation method. Adopting proper cropping systems considering land suitability and capacity building of farming community in improved soil, crop and water management technologies would enhance the water productivity in an effective and sustainable manner.

Resource conservation interventions (laser land leveling, bed & furrows and zero tillage) can save 50% water and increase the crop yield upto 25% [32]. Sarwar [33] concluded that laser land leveling (LLL) can enhance crop yield from 20 to 35% and save 25% irrigation water. Kahlown [34] evaluated the impact of resource conservation techniques on water and land productivity. These techniques were tested on 200 acres of land (Mona Reclamation Area) in LJC command. Halcrow [35] recommended increase in irrigation system efficiencies to 45% merely by educating farmers on use of water in fields and by water distribution management on farm lands in form of lining water lines. The use of RCIs has proved several benefits to wheat farmers. Water can also be saved up to 34% by using ridge furrow of 660 cm wide [36-37].

The demand side management by optimized cropping pattern can improve crop productions and reduce the pressure of water shortage to some extent. The growth of high delta crops should be avoided. The cropping pattern needs to be rationalized so that the pattern of crops provides high water productivity and crop yield. The traditional pattern of wheat-rice has resulted better economic return. The sugarcane crop has resulted poor water productivity and allocation of resources. The water productivity of Orchards is very high and also these are high value crops. Shakir [38-39] suggested that several organizations are involved in management and distribution of water, on farm water management and revenue collection at canal command levels in Pakistan. Generally there seems to be lack of coordination and overlap of activities among the agencies causing poor overall performance. It may be advisable to provide a single administrative unit bringing together all stakeholders. The last but not the least, the participation of farmers in management needs to be enhanced in real terms to create within them a sense of owner ship of the system. The prospective measures for reducing shortfall included enhancement in canal supplies, change in cropping pattern, canal lining and on farm water management.

The constraints for implementing the optimization strategies identified in the study include: physical constraints due to poor operation and maintenance of the system and inadequate water control structures. Institutional constraints due to public sector monopoly, lack of coordination among different institutions and agencies, limited specialization and skilled staff, limited involvement of farmers in irrigation management. Financial and economical constraints due to inadequate cost recovery and provisions for operation and maintenance of irrigation system.

8. CONCLUSION AND RECOMMENDATIONS

The case study reveals that there is much provision on the rivers in Punjab for small storages using inflatable rubber dams. Several benefits including ground water recharge, diversion weirs for small hydropower plants, creating artificial lakes for recreation purposes and for water supply by the use of rubber inflatable dams can be successfully achieved having flexibility in operation during lean and flood period. Total 27 sites, as summarized in

Table 5, were considered feasible for constructing inflatable dams which indicated their potential in Pakistan. Further detailed studies are recommended emphasizing both the technical and economical aspects of inflatable rubber dams before their construction in Pakistan.

For sustainable water resources management, it is recommended that optimized structural reforms from river to root zone of crops i.e., lining of channels, remodeling/up-gradation of hydraulic structures and the adoption of Resources Conservation Interventions (RCI) and high value/ yield crops at farm level are utmost imperative in addition to developing new reservoirs.

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Research Article

Environmental Issues and Concerns of Groundwater in Lahore

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Abstract: In Pakistan, about 80% population in large cities and do not have access to clean water. Demand for fresh water supply has increased many times to meet domestic and industrial requirements. Lahore is the second largest populated city of Pakistan with estimated population of 10 million, with an area of 1014 km^2. It is located on the alluvial plain of Indus Basin on an altitude ranging between 682 ft. to 698 ft. above mean sea level and is bounded by Ravi river in the North West and BRBD Canal on the east and average annual rainfall recorded is about to 675 mm. Groundwater is the only source of domestic and industrial use in the city. The un-planned excessive pumpage of groundwater as 1645 cusec has threatened aquifer depletion along with other socio-economic issues. After creation of Pakistan, the groundwater level in Lahore city was as 15-16 feet which has now reached its depth 100 feet. Under the circumstances, IRI starts a monitoring study, in this regard to get the first hand awareness of the situation and to suggest some remedial measure there at and 60 piezometers have been installed in Lahore city area and along Ravi river to monitor the time rate changes in groundwater levels and its quality. These Piezometers have been installed in batteries (3 in each) at the different depths to monitor the vertical profile and quality of groundwater. The authors have observe a great threats to groundwater in the Lahore aquifer identifying as over pumpage, industrial effluents, precipitation of air pollution, sewage and street runoff etc. Another factor of this research work is that the groundwater levels fluctuate with the river gauge which indicates that Ravi river is contributing towards aquifer recharge whereas groundwater levels in Lahore city is falling at the rate of 2.5 ft. per year. Moreover, the quality of groundwater assessment in the river reach from Ravi Syphon to Mohlanwal has been made and is found the worst near Shahdra (Lahore city).

Keywords: Groundwater, aquifer,piezometers, effluents, ravi river, artificial recharge, Lahore

1. INTRODUCTION

As it has been indicated in vision 2025 that a serious water scarcity situation may occur in Pakistan and the country may suffer badly if necessary measures are not taken from today for the management of water resources. Pakistan is the sixth largest populated country of the world with a population of more than 175 million and a population growth rate as 2.1 percent. Since last many years, rapid increase in population has resulted in over extraction of groundwater especially in the urban areas to meet with human demands due to which underground water table is depleting at alarming rates.

Groundwater is a vital and open access source and dependence on it has increased dramatically in the last six decades especially across South Asia. Together South Asia and China account for more than half of global groundwater use. Over the past three decades, South-Asia has emerged as the largest exploiter of groundwater in the world. Due to increasing shortage and inconsistencies in surface water supplies, groundwater acts as the mainstay for agriculture in India, Northern Sri Lanka, the Pakistani Punjab, Bangladesh, and the Northern China Plain. In India, groundwater provides 60 % of the total agricultural water use, accounting more

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than 50 % of the total irrigated area. In the North China plains, groundwater extraction accounts for 65, 70, 50 and 50 % for the total agricultural water supply for the provinces of Beijing, Hebei, Nanan and Shandog, respectively [1]. In Pakistan, groundwater contributes more than 50 % to the total crop water requirements in the Punjab province which produces 90 % of the national grain output [2]. However, the flip side of this large scale exploitation of groundwater is that the future of irrigated agriculture, which is increasingly blooming on groundwater, stands threatened due to its unsustainable use and consequent serious environmental outcomes.

Groundwater is the world's most extracted raw material with withdrawal rates in the estimated range of 982 km^3/year as per 2010 data. About 60% of groundwater withdrawn worldwide is used for agriculture; the rest is almost equally divided between the domestic and industrial sectors. In many nations, more than half of the groundwater withdrawn is for domestic water supplies and globally it provides 25% to 40% of the world's drinking water [3].

It has been estimated that about 60-70% population of Pakistan depends directly or indirectly on groundwater for its livelihood [4]. Pakistan is the 4th largest user of groundwater in the world after India, USA and China. In Pakistan irrigated agriculture contributes about 90% of food production and groundwater has become vital for irrigated agriculture in the country especially in Punjab province. Lahore, is the 2nd largest city of Pakistan and according to the 1981 census, Lahore had a population of 2.7 million which increased to 6.4 million in 1998 [5]. Now the estimated population of Lahore is more than 10 million having growth its rate as 4% per year. Issues of groundwater in the Lahore are multifarious and complex in nature. The groundwater level of Lahore after the creation of Pakistan was close to surface at the depth of 15-16 feet but as the city started expanding, it reached upto 70 feet in the period of thirty years (1959-1989) which show the decline of more than 50 ft. in water-table in Lahore city [6, 7].The un-planned pumpage of groundwater results salt-water intrusion into fresh groundwater due to which sweet groundwater resource is becoming scare in the aquifer underlying the Lahore city. The only source to recharge Lahore aquifer is Ravi river which remains nearly dry except during monsoon season. Currently, groundwater level has declined to more than 100 feet at many places. Natural recharging of groundwater aquifer is almost negligible due to construction activities and pavements of streets and roads. Untreated waste water from municipal and industrial units is being discharged into the Ravi river [8, 9]. Pollution in the Ravi river is contributing directly towards the deterioration of groundwater quality in the aquifer underlying the Lahore city [10].

In developing countries including Pakistan where environmental legislation either does not exist or is not implemented to the desired standards, the groundwater situation is alarming. The main objective of this study is to investigate the potential environmental threats to groundwater and suggest some mitigation measures for groundwater management in the urban localities like Lahore city area.

The study area consists of the Lahore City and its surroundings including a reach of Ravi river from Ravi Syphon to Mohlanwal as shown in Fig. 1. Lahore is the 2nd largest city of Pakistan and is considered to be the 24th largest city in the world. Climatic of Lahore is characterized by large seasonal variations in temperature and rainfall. Mean annual temperature is approximately 24 °C ranging from 36°C in June to 12 °C in January. The highest maximum temperature 48 ^{0}C (118 °F) was recorded on June 9, 2007 while the lowest temperature recorded in Lahore was -1 °C on 13 January 1967. The average annual rainfall recorded is close to 675mm, which can vary from 300 to 1200mm. Approximately seventy five percent of the annual total rainfall occurs in monsoon season in the months from June to September and contributes approximately 40mm to groundwater recharge in a normal year [11]. Lahore area is underlain by a significant thickness of alluvial deposits, up to 300 m in depth as investigated by WASID during the period 1961-62 [12]. The sedimentary complex has a thickness of more than 300 meters and is composed of unconsolidated alluvial sediments, consisting of sand, silt and clay in different proportions [13].

2. MATERIALS AND METHODS

Different experiments/Observations have been carried out in the study area to collect the required data to assess the existing scenario of groundwater as discussed below:

2.1 Installation of Piezometers

For having proper awareness of groundwater resources, it is imperative to use a mechanism of piezometers. For this purpose nineteen piezometers have been installed at different location scattered in the study area as depicted in Fig. 1. Geographical locations of all the piezometers have been determined by using Global Positioning System (GPS). To monitor the spatial and temporal impact of the pollution in groundwater through Ravi river, an experimental setup consisting of 50 piezometers has been laid along the river as shown in the Fig. 2. These piezometers have been installed on three sites along the River, viz: Ravi Syphon, Shahdra Bridge and Mohlanwal in the shape of triangular battery consisting of three piezometers at a depth of 150 ft., 100 ft. and 50 ft. on both sides of the river. First battery on the edge of river, second at a distance of 500 ft. and 1500 ft. distance from the river.

2.2 Aquifer Behavior (Water Levels)

Groundwater levels have been measured by piezometers installed in the city area and along the river biannually (pre-monsoon and post-monsoon) since 2009. The data so observed have also been analyzed to visualize the aquifer conditions in the study area.

It has been observed that as population of the Lahore city is expanding and accordingly groundwater abstraction is increasing to meet with the domestic needs of consumers with 100% reliance on groundwater. Groundwater levels from 50 piezometers installed at different locations as mentioned above were observed and found that groundwater levels are falling at most of the locations. The fall of groundwater levels at Shahdra is found greater than as compared to those at Ravi Syphon and Mohlanwal sites which indicate the excessive pumpage in the vicinity of Lahore. The groundwater level fluctuations at Shahdra have been represented graphically in Fig. 3 and Fig. 4. Due to higher rate of pumpage than that of recharge of aquifer, depth to water table is continuously increasing which results expanding of depression zone area. The natural surface level (NSL) and groundwater levels for year 2009 to 2013 (ft.amsl) have been plotted as Fig. 5 to 12. This indicates demographic pressure on aquifer near Lahore city. It has been observed that the depression zone with water level below as 38 m is also expanding continuously @ 24 km^2 per year. Depression zone has increased from 52 km^2 in 2007 to 150 km^2 in 2012 [4].

Piezometers were also installed along Ravi river at three locations, i.e., Ravi Syphon, Shahdra. Water levels either from left or right side of river at Ravi Syphon, Shahdra and Mohlanwal are falling at most of the locations with the passage of time. The depth to water table observed in piezometers is more at Shahdra as compared to those at Ravi Syphon and Mohlanwal sites [10] which indicate the excessive pumpage in the city.

2.3 Groundwater Quality

Groundwater quality at downstream from Ravi Syphon to Lahore city has deteriorated. It is observed that the color of groundwater near Lahore city has been varied from colorless to yellowish and its odoris now to objectionable with turbidity ranging from 2 to 4 NTU. Heavy metals have also been found in the groundwater samples and the concentration of lead (Pb), Nickel (Ni) and number of E. coli levels exceeded the permissible limits of drinking water quality [14]. Municipal landfills are considered another sources which have a serious threat to urban environments and a great source of pollution especially groundwater [15]. The fluctuations in groundwater levels and quality to develop the link between River flows and groundwater in the underlying aquifer was done by water samples from the piezometers installed along the river, away from the river and at different depth. Groundwater quality has been analyzed in different directions like along the river, away from the river, vertically downward and with the passage of time to derive some conclusions. In addition to surface water (river and drains), groundwater samples from all 50 piezometers installed at different locations and depths along the river have been taken through

a specially designed sampler to correlate the quality of water in river with quality of groundwater. Groundwater water samples from piezometers installed at three sites of Ravi Syphon, Shahdra and Mohlanwal at different depths were collected and tested. Electrical conductivity (EC) of groundwater at all sites has been graphically plotted as shown Fig. 13 to Fig 18.

The results analysis of groundwater from piezometers installed at Ravi Syphon site indicate that groundwater quality downstream Ravi Syphon on both sides of the River at all depths (50 ft., 100 ft. and 150 ft.) is good and is not deteriorating. This indicates that groundwater quality perpendicular to the river from Left side or right side (L_1, L_2, L_3 or R_1, R_2, R_3) is good and can be used as bench mark for comparison of groundwater quality while moving downward. The data analysis at Shahdra site reveals that EC values at 50 ft. depth are more while the value at 150 ft. depth is lesser on both sides of the River. Groundwater quality at 50 ft. depth at R_3P_3 and L_3P_3 is deteriorating. At Mohlanwal site, EC values of piezometer installed at 50 ft. depth are more as compared to those at 100 ft. and 150 ft. depth on left side while lesser on right side of the river.

It is clear from data that groundwater quality at L_3P_3, R_1P_2 and R_3P_3 (Shahdra sites) is deteriorating. During 2011 and 2012 the value of EC at R_3P_3, L_3P_3 (50 ft. depth) has increased rapidly. It indicates that quality of groundwater at 50 ft. depth is deteriorating with the passage of time. Overall results of analysis of groundwater samples along Ravi river indicate that the quality of water is deteriorating, moving downstream from Ravi Syphon to Lahore.

EC values of groundwater on left side of the river at location (L_3) of Shahdra site at various depth 50 ft, 100 ft and 150 ft for the year 2012 plotted in Fig. 13 indicates that water quality of shallow groundwater (50 ft. depth) is deteriorating more as compared to 100 and 150 ft depths.

Water quality of shallow groundwater (50ft depth) along left side of the river at Location (L_3) of Shahdra site for the years 2010, 2011 and 2012 were compared as indicated in Fig. 14. The data indicates that with the passage of time water quality of shallow groundwater becomes poor. It is clear from Fig. 14 that values of EC at 50 ft depth for the year 2012 are more as compared to those of 2010. Shallow water quality data along the river from D/S of Ravi Syphon towards Mohlanwal site were also compared for the year 2011. The Fig. 15 indicates that as we go down from Ravi Syphon towards Lahore, water quality is deteriorating. The Fig. depicts that quality of shallow groundwater at Shahdra site is more poor and deteriorated and then from Shahdra to Mohlanwal it is improving due to dilution effect. By comparing three sites Ravi Syphon, Shahdra and Mohlanwal, water quality is becoming deteriorated / poor at Shahdra site along the river. Similar trend occurs along right side of the River from D/S Ravi Syphon to Mohlanwal as shown in Fig. 16, Fig 17 and Fig 18.

Overall result of analysis indicates that groundwater quality is deteriorating more at Shahdra (as compared to that of Ravi Syphon and Mohlanwal) due to entrance of effluents through different drains into the river. The data at Shahdra site along both sides of the river indicates that quality of shallow water at depth of 50 ft at R_3 and L_3 is deteriorating more with the passage of time.

3. POTENTIAL THREATS TO LAHORE AQUIFER

Being a thickly populated, hub of industrial activities and provincial capital Lahore has become a city of complex issues related to groundwater pollution. A wide range of pollutants generated by natural and human activated are contributing towards the degradation of groundwater in the area.

3.1 Population Growth

Population growth has a direct impact on depletion of groundwater resources. Abstraction of groundwater increases as population grows and over-exploitation of aquifer results in decline of groundwater levels. Temporal trends of depth to water table and population growth in Lahore are depicted in Fig. 19 and major consumer of groundwater in Lahore is WASA (Fig. 20).

3.2 Over Pumpage

Groundwater is the only source of water supply for

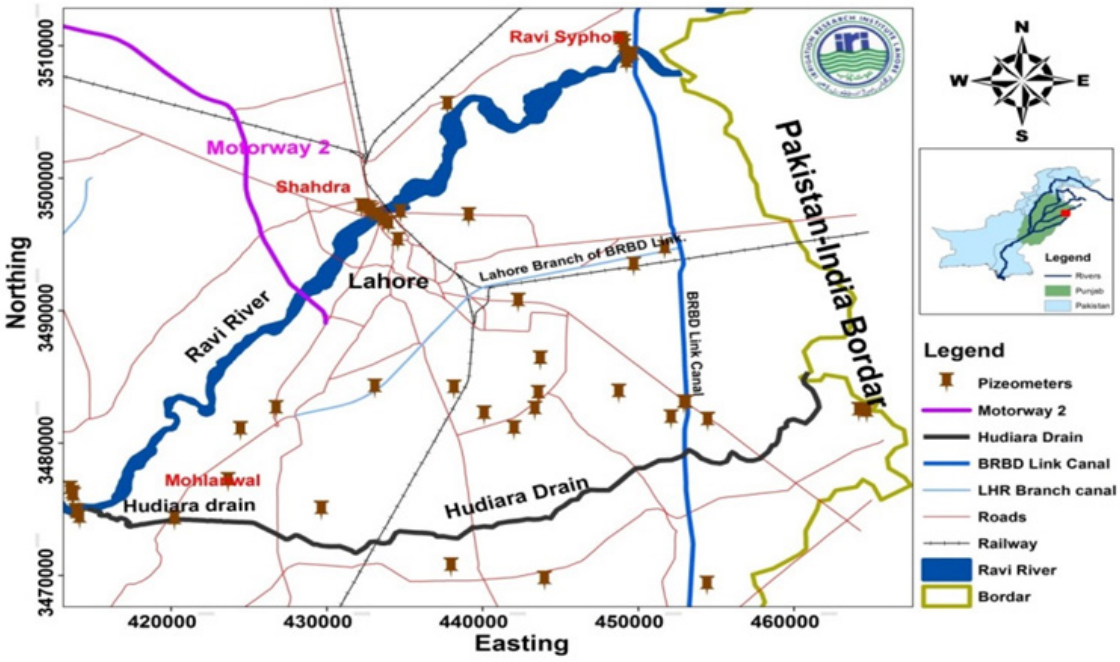

Fig. 1. Map of study area showing the Piezometers installed in the Lahore city.

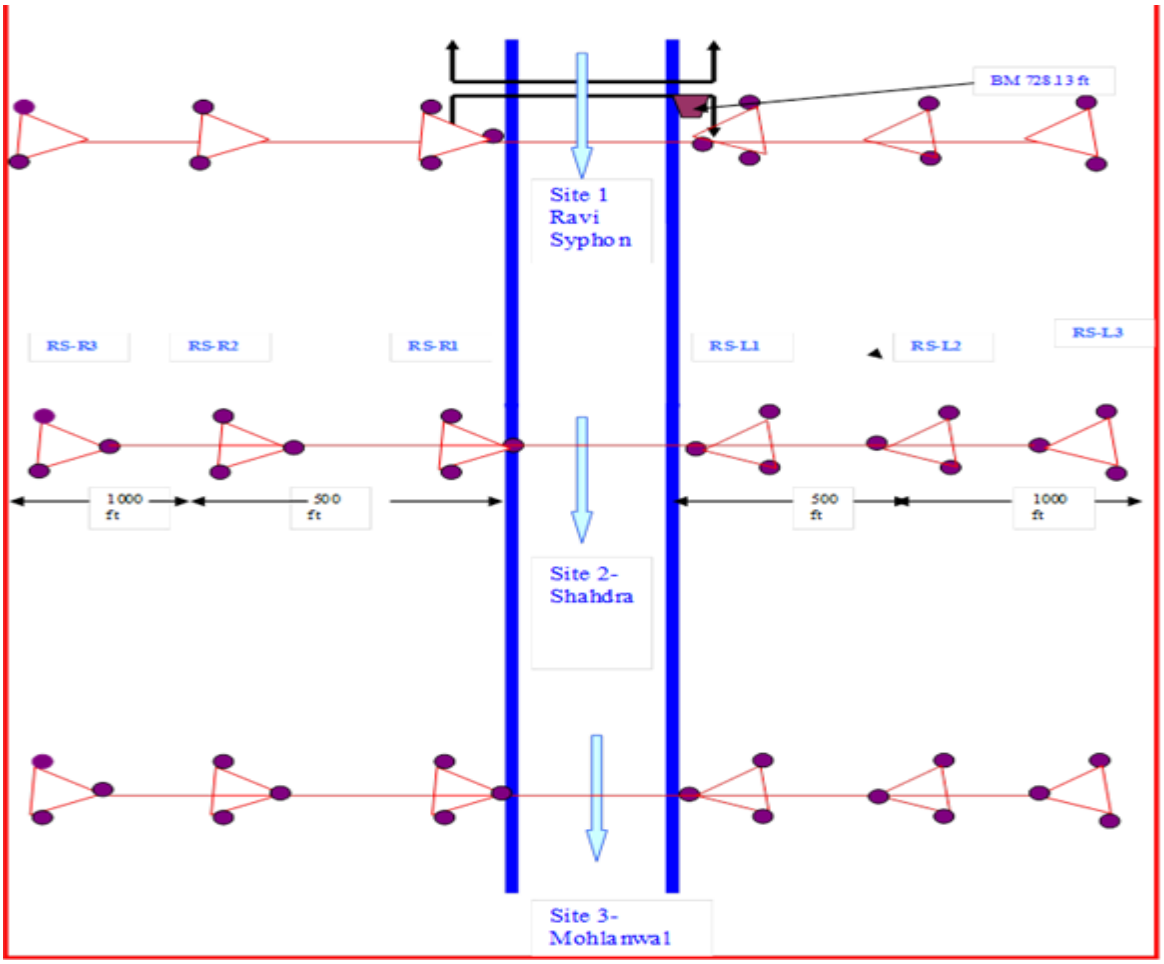

Fig. 2. Schematic diagram of Ravi river showing locations of Piezometers [21].

Table 1. Discharge and quality of wastewater in the major drains in Lahore city.

Sr. No.	Name of Drains	Discharge (Cusecs)	TDS (ppm) (May 2011)	TDS (ppm) (March 2012)
1	Mehmood Botti Drain	20.87	775	1117
2	Shad Bagh Drain	139	663	1067
3	Farrukhabad Drain	219	1088	1627
4	Bhuda Ravi Drain	41.99	1006	1100
5	Main Outfall Drain	193	627	1154
6	Gulshan-e-Ravi Drain	246.5	897	1035
7	Babu Sabu Drain	270.7	760	1135
8	Hudiara Drain	535.7	1197	1506

Table 2. List of potential sites for artificial recharge of aquifer in Lahore by rainfall harvesting.

Sr. No.	Name of site/location
1	Jallo Park, Lahore.
2	Along BRBD Canal Right Bank, near Barki Village, Lahore
3	Padhana Village, Barki Road, Lahore (Western Side of Lake).
4	Lahore International Airport Lahore, Post No. 4, Civil Aviation Authority, Southern end of Runway
5	Walton Airport, Ferozepur Road, Lahore.
6	Northern Plot of Badshahi Mosque, Lahore
7	Field Research Station, Niazbeg, Multan Road, Lahore.

Lahore city. WASA, Lahore has installed 480 tube wells of different capacities at a depth of ranging from 150 m to 200 m for supplying water to the citizens of Lahore which are extracting about 1170 cusec of groundwater per day for drinking purpose. In addition to WASA tube wells, a large number of private tube wells installed in housing schemes are roughly pumping 100 cusec water daily. Water is also being pumped by industries at the rate of approximately 375 cusec [16]. In this way total extraction of groundwater in Lahore becomes 1645 cusecs. Over exploitation of groundwater causes many serious environmental concerns like salt water intrusion, increase in pumping cost, increase in installation cost of tube wells, land subsidence, land sliding, development of sinkholes, etc.

3.3 Urbanization and Commercialization

Urban sprawl is the fastest growing threat to local environment and quality of life. Lahore city is adversely affected by uncontrolled and unplanned increasing urban industrialization and commercialization. As urban areas expand, environmental problems like losing green space, decreasing groundwater recharge area, degradation of natural ecosystem and deterioration of water resources are increased. The impact on groundwater quality from urban sprawl is attributed by the combined effect of population and land use change. Urbanization trend in Lahore is depicted in Fig. 21.

3.4 Low Flow in Ravi River

Ravi river is the smallest of five eastern rivers of the Indus River System (IRS). It enters in Pakistan at Jassar, about 120 km upstream of Lahore and joins the Chenab River near Kabirwala after flowing down about 520 km. The average annual flow of the Ravi river in Pakistan territory was 7 million acre feet (MAF) during the period 1922 to 1961 but due to Indus Water Treaty of 1960 between India and Pakistan, right to use the water of this river were allocated to India. The average annual flow from 1985 to 1995 was recorded as 5-MAF which was further decreased to 1.1 MAF in years 2000-2009 due to construction of hydropower projects/ dams on Ravi river by India. It results in lowering in groundwater level in Lahore and its adjoining

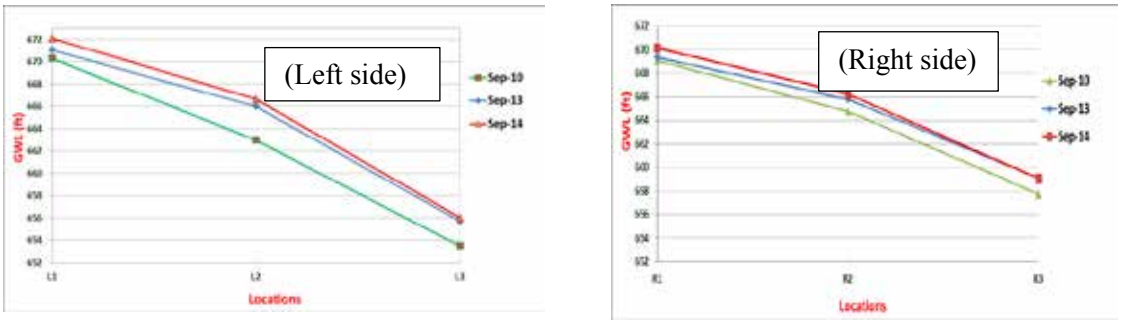

Fig. 3. Groundwater levels fluctuations at Shahdra site.

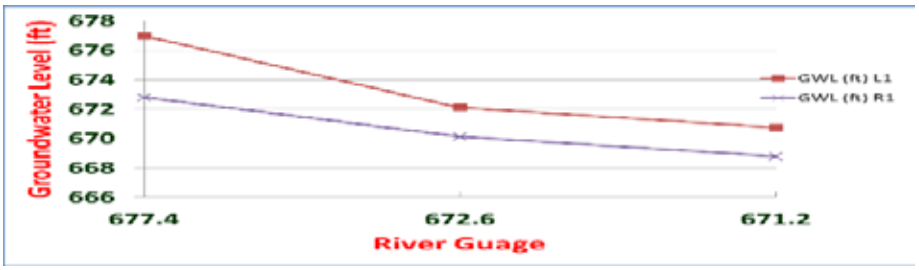

Fig. 4. Fluctuation of groundwater level with River gauge at Shahdra.

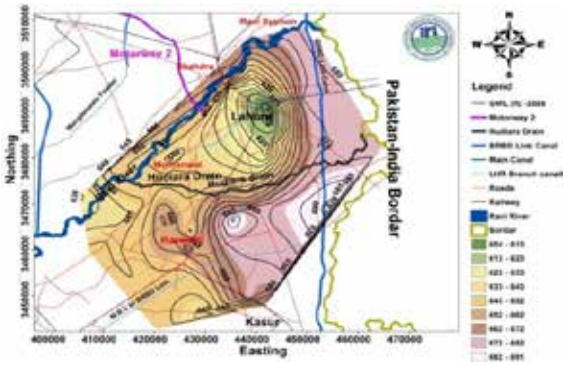

Fig. 5. Groundwater levels in the Lahore city for year (2009).

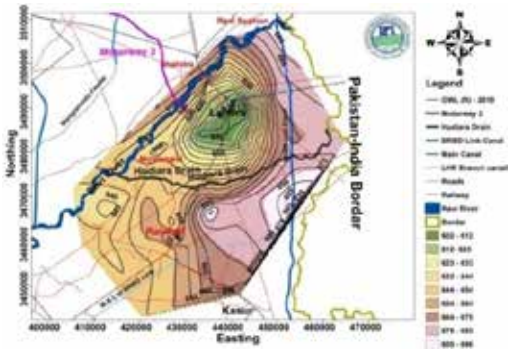

Fig. 6. Groundwater levels and depression in Lahore (2010).

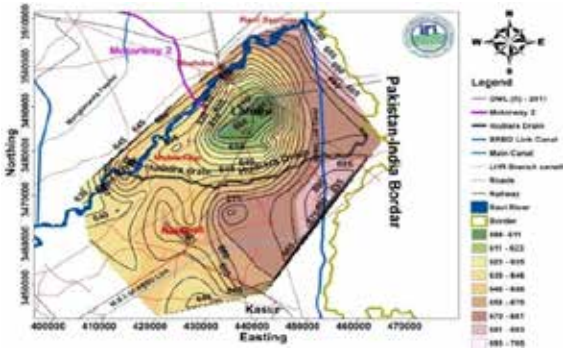

Fig. 7. Groundwater levels and depression zone area in Lahore (2011).

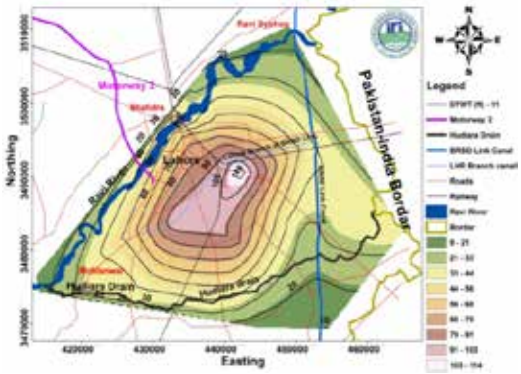

Fig. 8. Depth to water table with depressio area in Lahore (2011).

area. Ravi river seems to be the main source of recharge in the North-West of Lahore. For the last two decades, Ravi river remained almost dry except in monsoon, so recharge from River has seriously decreased. Under these circumstances on one side recharge to the aquifer has decreased tremendously and on the other side the ecosystem in the river has suffered badly and river has become a "sludge carrier" (Fig. 22).

3.5 Sewage and Street Runoff

Urban population in the Lahore is increasing at an alarming rate of 4% per year which is leading towards a continuous increase in domestic sewage. This sewage coupled with street runoff is a severe threat to groundwater as a part of it ultimately leaches down to groundwater. It was estimated that discharge of waste water of Lahore city into Ravi river was about 990 cusecs in year 2006 [17] and now has crossed to 3,304 cusecs through drains and various pumping stations without proper treatment [16] as depicted in Fig. 23.

3.6 Surface Drainage Network

A network of surface drains in Lahore city(Fig. 24)carries wastewater from various sources and ultimately enters the Ravi river. These are earthen channels which causes the leaching of various pollutants directly to groundwater. The quality of wastewater in drains is deteriorating with the passage of time as shown in Table 2 [10].

3.7 Industrialization

As mentioned already, Lahore has become hub of industrial activities in the country. A large number of industry pertaining to textiles, chemicals, auto parts, electric appliances, machinery, food, restaurants, plastic and pvc retailers that are based in the beautiful Lahore city are polluting the environment. These Industries are located at Kala Shah Kaku, Lahore Sheikhupura road, along Lahore band road, Quaid-e-Azam Industrial estate at Kot Lakhpat, and Multan road in Lahore city and using huge amount of groundwater for processing raw material and finishing the products. Instead of these industrial estates, a large numbers of in house small industrial units are working within the Lahore city which are discharging wastewater into sewerage system without treatment. Domestic and industrial effluents contain organic and inorganic pollutants, which deeply percolate through the soil depending upon the soil nature and sooner or later deteriorate the groundwater quality. Flow in Ravi river during the winter is insufficient to wash off wastewater pollution [10]. The environmental profile of Pakistan indicates that about 40% of deaths are related to waterborne diseases spread by water pollution, mainly due to the sewage and industrial wastewater contamination to drinking water distribution systems.

3.8 Dumping of Solid Waste

Typically Municipal Solid Waste (MSW) consists of household waste, commercial waste and institutional waste. Unscientific dumping of solid waste always poses serious environmental problems on groundwater. Leachate produced at landfill contains thousands of complex components and it becomes part of groundwater after infiltration. With reference to Lahore city, three sites were selected which are located at Mehmood Booti, Saggian and Baggrian for dumping of solid waste. Groundwater is suspected to be contaminated due to unscientific, unsafe, unplanned and traditional selection of these sites. At least three-quarters of the total waste generated (3800 tons/day) in Lahore is dumped at these sites without proper treatment. According to a previous study, it was found that most of groundwater samples collected from nearby these landfill sites contain pollutants and their concentration level in groundwater is higher than prescribed by Pakistan Standards and Quality Control Authority (PSQCA) and concentration of Arsenic in drinking water is higher than WHO criteria[18]. It was reported in the Daily newspaper (20 May, 2008), that according to United Nations Environmental Program (UNEP)'s data about 47% drinking water in Lahore city was contaminated due to presence of various hazardous toxic elements [19].

3.9 Agricultural Runoff

Excessive and uncontrolled use of chemical fertilizers, pesticides and herbicides promotes contaminated agricultural run-off. This not only pollutes the surface drains but the water trickling

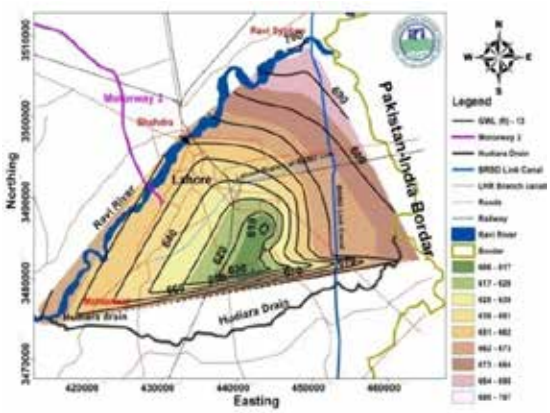

Fig. 9. Groundwater levels and depression zone area in Lahore for the year 2013.

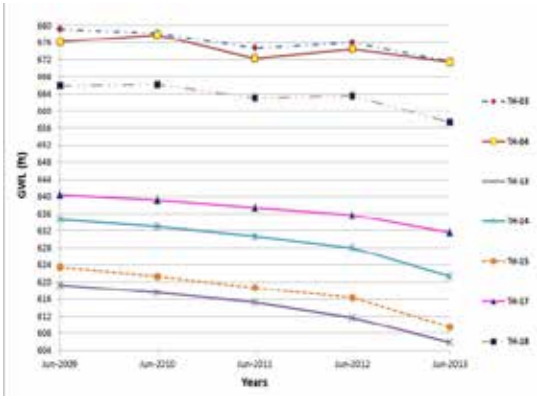

Fig. 10. Decline in groundwater level in Lahore from 2009 to 2013.

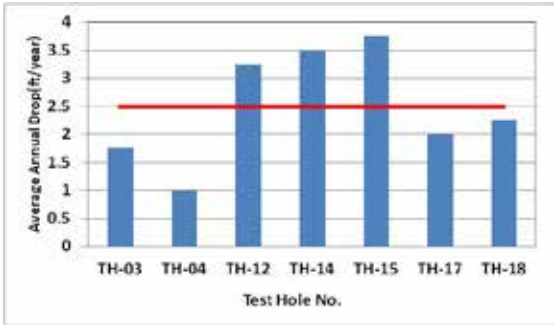

Fig. 11. Average depletion rates of groundwater in Lahore from 2009 to 2013.

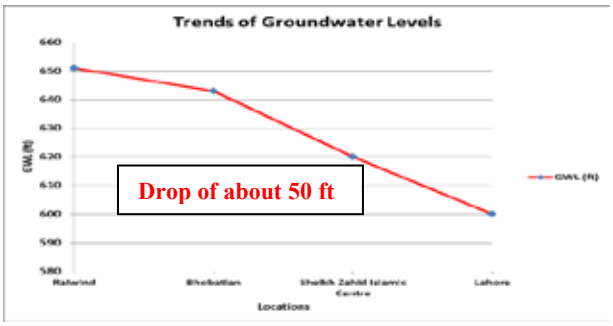

Fig. 12. Longitudinal profile of groundwater levels from Raiwind to Dharampura, Lahore for the year 2010.

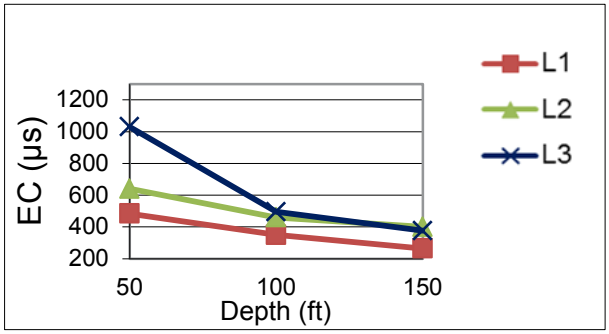

Fig. 13. EC (µs) at Shahdra site vertically downward for the year 2014.

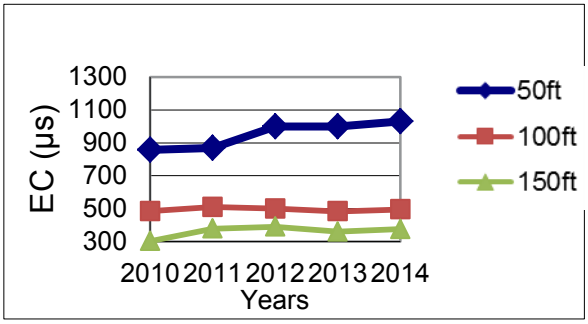

Fig. 14. EC (µS) at L3 Shahdra site w.r.t. time.

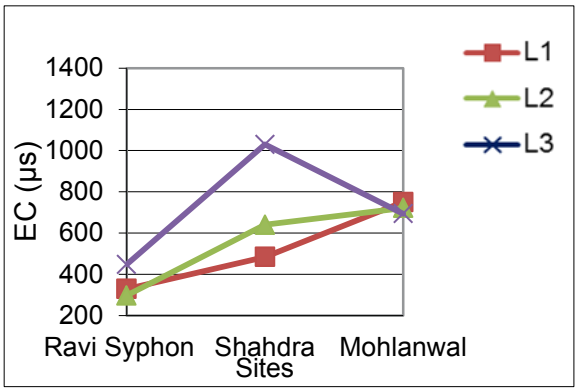

Fig. 15. EC (µs) along river from Ravi syphon to Shahdra and to Mohlanwal at a depth of 50 ft for the year 2014.

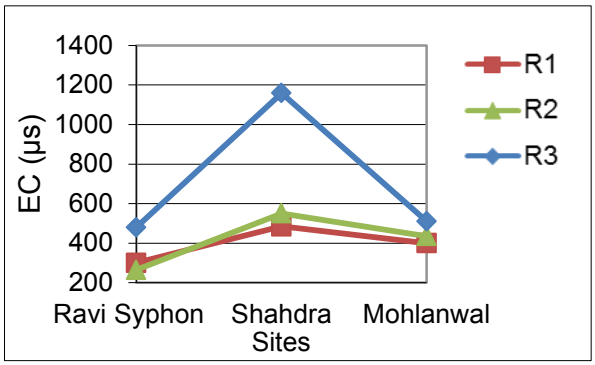

Fig. 16. EC along river from Ravi syphon to Shahdra and to Mohlanwal at a depth of 50 ft for the year 2014.

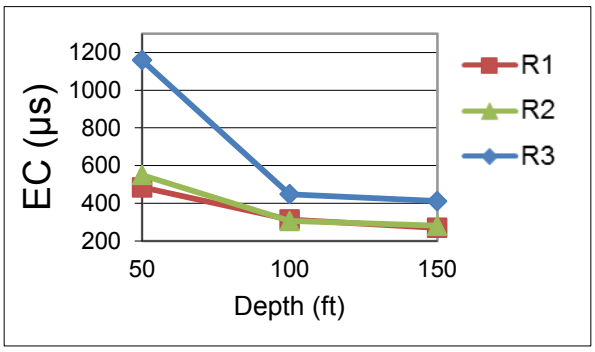

Fig. 17. EC at Shahdra site vertically downward for the year 2014.

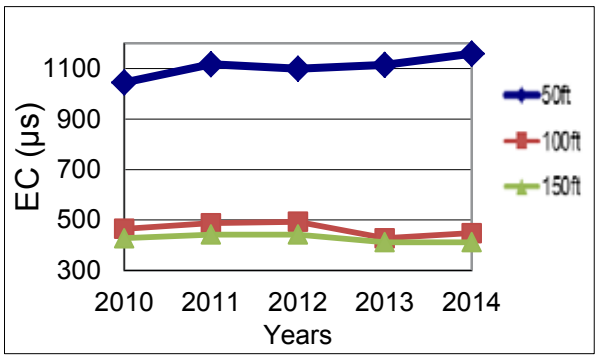

Fig. 18. EC at R3 Shahdra Site w.r.t. time.

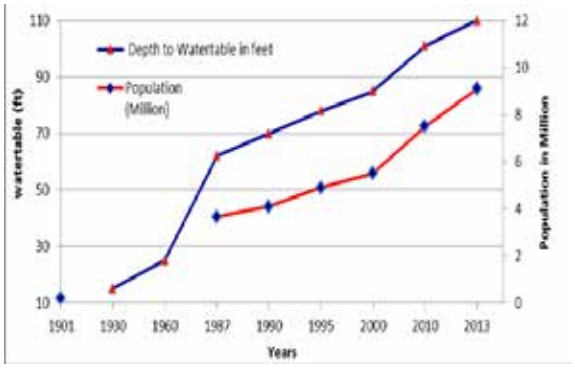

Fig. 19. Trends of population and water table depth in Lahore area.

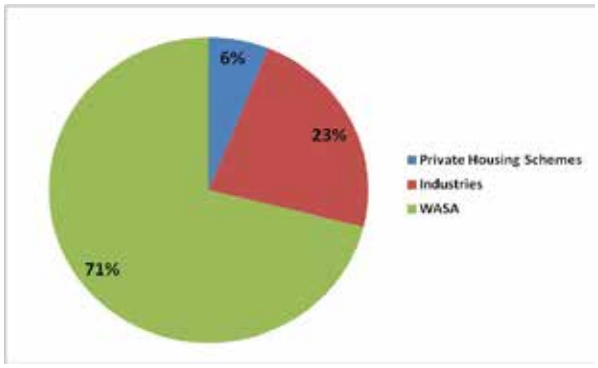

Fig. 20. Major groundwater consumers in Lahore.

down to lower layers of soil causes a severe contamination of the natural aquifer in surrounding areas of Lahore. Over abstraction of groundwater prompts recharge from the surface water drains, which themselves are severely contaminated. Different drains like Hudiara drain which collects surface runoff from agriculture fields from India and Pakistan and pollutes the groundwater in Lahore and surrounding areas.

3.10 Air pollution

Vehicular and industrial emissions comedown with rainfall in the shape of acid rain which increases the acidity of surface water body like lakes, rivers and drains due to which aquatic life is affected adversely. These toxic pollutants leach down from soil surface to groundwater. Acid rain dissolves all the useful minerals from the top soil like potassium, calcium, magnesium and leaches them down to the aquifer. Similarly aluminum is also activated by acid rain which causes the death of aquatic life and contaminates the groundwater reservoir.

In addition to the threats mentioned above, lack of proper coordination between various stakeholders and awareness among the various groundwater users are also of prime concern and contribute significantly in degradation of the groundwater resources in the city.

4 MANAGEMENT OPTIONS

Groundwater is a precious gift of nature and is playing a vital role for the existence of life at the planet. This natural resource is being used for drinking, agricultural, industrial, livestock and other uses and is continuously under threat. Groundwater reservoir is a natural system which is balanced naturally by different sources of recharge including rainfall, dams/lakes, ponds, rivers, canals, water courses and irrigated fields etc. Different inflows and outflows from the system are balanced automatically and system remains under equilibrium conditions. Human being is the major player who plays with the nature to meet with its different increasing needs of food and fiber. Human activities interrupt with the natural ecosystem and balance is disturbed which then creates various multidimensional issues in the real world, which we call environmental threats. For example, when we talk about the Lahore aquifer, we have reduced/ hindered all most all the sources of recharge of aquifer and on the same time extraction of groundwater is increasing tremendously. Such scenario leads to environment degradation of groundwater reservoir with respect to quantity and quality. Some recommended options are as under:

4.1 Artificial Recharge

To maintain the quantity sustainable, the recharge of aquifer is the only and only viable solution for replenishment of the rapidly depleting aquifer no doubt we should control pumpage as well. Recharge of aquifer can take place naturally, but if it is not possible we should intervene and should devise the artificial ways and means for recharging the aquifer.

During the year 2008-09, Irrigation Research Institute conducted preliminary survey and dug sixty exploratory boreholes in the field at various critical site in Punjab to explorer aquifer characteristic and soil stratification to identify the potential sites for artificial recharge of aquifer. Soil samples from all these sixty sites were collected and analysed for determination of hydraulic conductance and profile lithogly [20]. Irrigation Research Institute installed fifty piezometer during the year 2009-10 in the shape of triangle at different depth in the field adjoining Ravi river in its reach from Ravi syphon to Mohnalwal to check the behaviour of groundwater levels, extent of pollution and to explore the aquifer characteristic and soil stratification in the area [21].

A variety of methods have been developed and applied to artificially recharge groundwater reservoirs in various parts of the world. Selection of the feasible methods is important and can be challenging. The methods may be generally classified as: i) the direct surface recharging techniques; ii) indirect recharge techniques; and iii) combination of surface and subsurface methods including subsurface drainage (collector wells), basins with pits, shafts, and wells, etc. Possible options for artificial recharge in Lahore area are:

(i) Rainfall harvesting at potential sites;

(ii) Lahore Branch Canal;

(iii) BRBD canal;

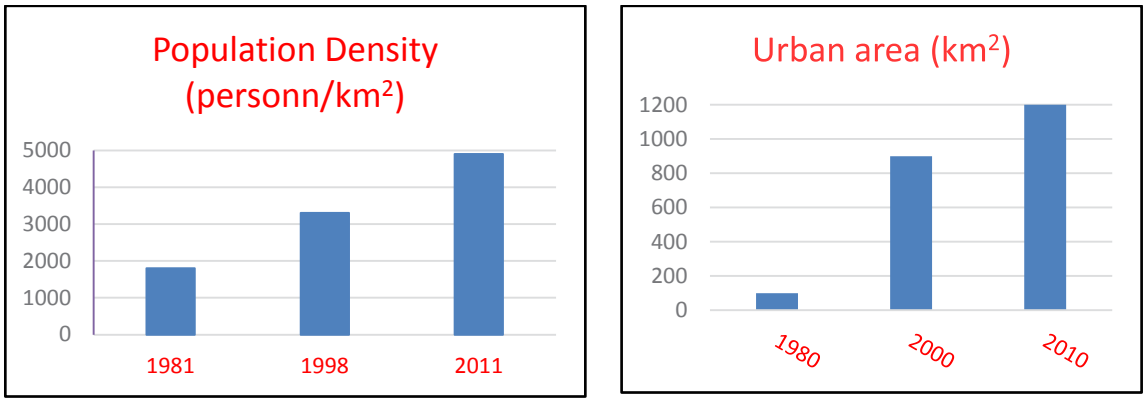

Fig. 21. Urbanization in Lahore.

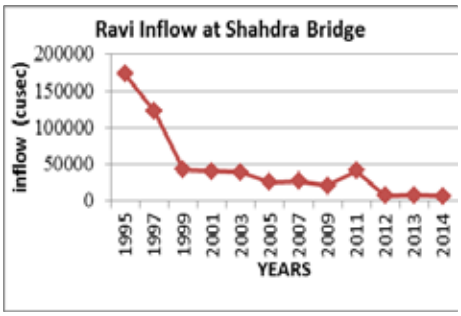

Fig. 22. History of water flow in Ravi river.

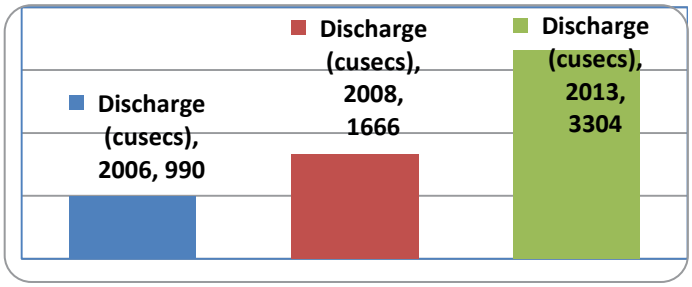

Fig. 23. Effluents being thrown into the Ravi river.

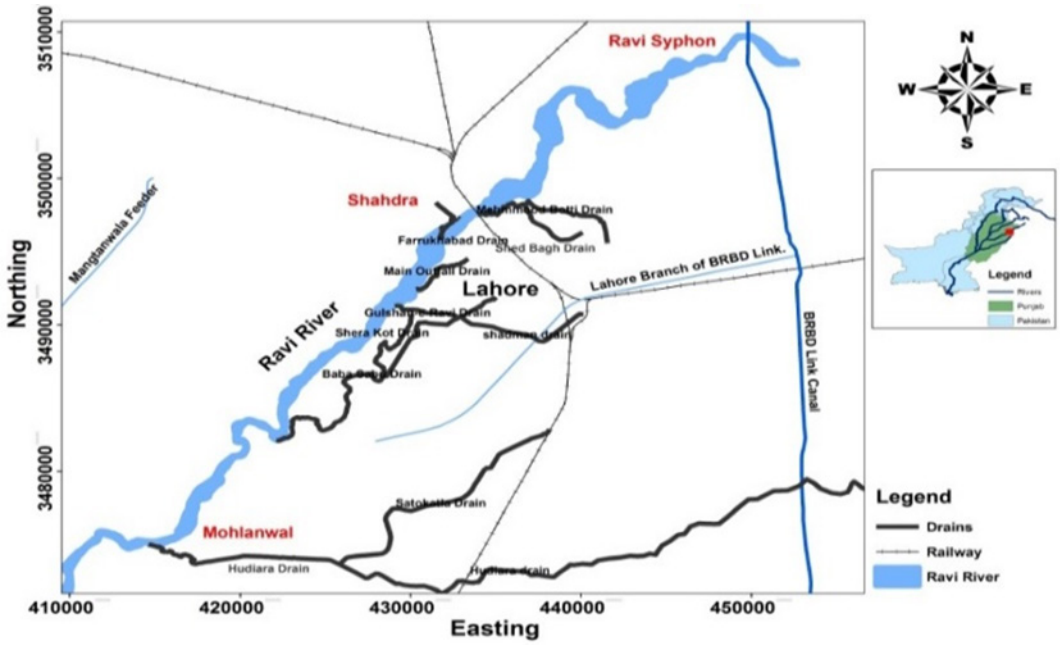

Fig. 24. Location of major drains in Lahore area entering into Ravi river.

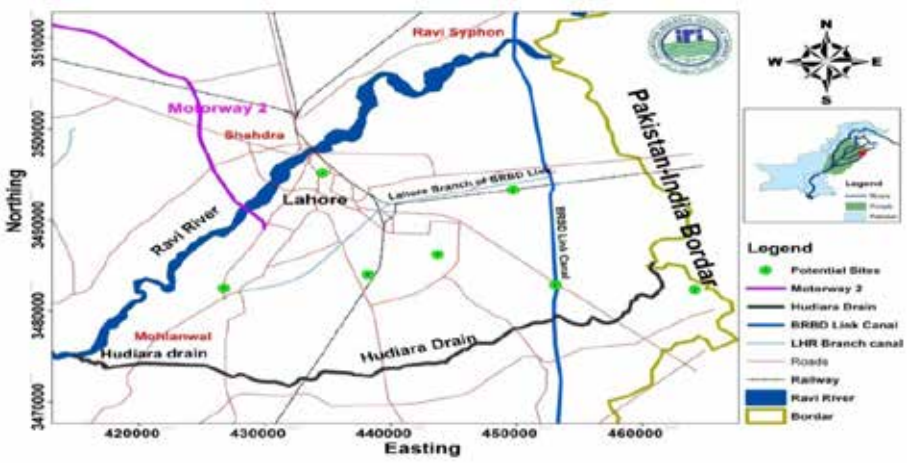

Fig. 25. Potential sites for artificial recharge in Lahore.

(iv) Ravi river by diverting more water in it;

(v) By constructing a ponds/lake between Ravi river and BRBD canal; and

(vi) Recharge wells at suitable sites.

4.2 Rainfall Harvesting

Rainfall is a natural source which can be harvested and diverted/injected to groundwater reservoir. It helps a lot to maintain groundwater potential and at the same time can we can avoid the street flooding and overflowing of drains/nalahs and choking of sewerage systems. Rainfall water, after some time, is comparatively of good quality and can safely be used for recharge purpose by adopting a suitable design mechanism.

Field surveys and sub-surface investigations have been carried out by IRI to identify potential sites for artificial recharge through rainfall harvesting. A list of such sites is given in Table 4 and is shown in Fig. 25.

These sites have been identified after physical and topographical surveys where a reasonable volume of rainfall is collected naturally in depressions and can be recharged. After physical surveys, sub-surface lithology and soil characteristics have been determined to ascertain whether the sub-surface strata support recharge or otherwise. It has been found that all these locations are hydrological, geo-hydraulically and geo-chemically feasible for recharging the aquifer.

4.3 Redressing the Surface Pollutants

The 2nd largest issue of groundwater is its continuously deteriorating quality which is of more concern as it deals directly with human health. Sources of groundwater pollution are normally manmade intervention on earth surface and in certain cases the salts in bed rocks. Most of the pollutants effluents like industrial, agricultural, municipal etc. are in liquid forms which leach down to groundwater. Some other are in solid form like solid waste heaps through which pollutant leach down to subsurface soil and then to groundwater. Some pollutants are in gaseous form like vehicular and industrial emissions, which return back to soil surface via acidic rains and percolate down to groundwater through unsaturated zone. Broadly speaking these are the surface pollutants.

As a first effort, their production at source should be reduced or minimized through scientific research and public awareness campaigns. For example, farmers must be educated to use less toxic and in limited/required quantity fertilizers, pesticides, weedicides, etc. Similarly, industrialists should be provided with scientific solution to recycle or treat the effluents at source instead of throwing it into nearby water body or injecting directly to groundwater which off-course is not less than a crime. In the same way, sever steps are required to be taken for control/mitigation of gaseous emissions. Regarding solid waste management we can go for use of geo-synthetic materials at landfill sites to avoid leaching of pollutants. Solid waste can

also be used to obtain energy. Regarding municipal effluents we should take care to avoid mixing of rainfall with such pollutants and should capture and harvest the rainfall separately and store it in surface or subsurface storages. Treatment plants should be adopted to make the industrial, municipal, and agricultural waste waters useable for some purposes like industries, irrigation etc. keeping in view the cost and need options into considerations. Control on over-pumping can be helpful to avoid mixing of saline-fresh water in the aquifer

5. CONCLUSIONS

i. Potential identified threats to groundwater reservoir in Lahore are uncontrolled and un-planned over-pumping, untreated effluents, lack of recharge of aquifer, lack of coordination between various stakeholders, etc.

ii. Groundwater levels in the city area are falling at an average rate of 2.5 ft. per year and even more than 3 ft. per year at certain locations due to excessive pumpage and less recharge.

iii. Groundwater in some locations in the city area has fallen more than 100 ft. below the natural surface level.

iv. Ravi river has become a source of pollution for groundwater reservoir underlying the Lahore city (due to low flows and throwing of effluents in it).

v. Groundwater quality in the aquifer is deteriorating with the passage of time and sweet water is becoming rare and out of reach and improves with the depth below natural surface.

vi. Groundwater quality deteriorates moving downward from Ravi Syphon to Mohlanwal and is the worst near Shahdra along the Ravi river.

vii. Ravi river can contribute towards recharging the aquifer as groundwater levels fluctuate with the river gauge.

viii. Quality of effluents in drains entering the River is deteriorating with the passage of time.

ix. Slope of hydraulic gradient line has been observed from Raiwind/Kasur to Lahore and steeper slope has been observed as the line approaches Lahore.

x. There is lack of awareness and communication/ coordination among different Government Departments/ agencies and the various stakeholders/consumers

6. RECOMMENDATIONS

6.1 General

i. Establishment of National Groundwater Management Board, Provincial Boards/Cells as Groundwater is contributing more than 50% for irrigation and almost more than 90% for drinking purposes in Punjab.

ii. Formulation of long-term policy framework and comprehensive master planning to guard against fast depleting groundwater resources.

iii. Enforcement of Canal & Drainage Act 1873 and Punjab Environmental Protection Act 1997 (Amended 2012) and compliance of NEQS and other relevant rules and regulations.

iv. Formulation of Special Regulations/legal frame work for sustainable use of groundwater in rural and urban areas.

6.2 Specific for Lahore

i. A working group consisting of inter-departmental experts and the members of civil society/NGOs to sit together to bridge the gap of coordination/communications.

ii. To strengthen the monitoring network for groundwater levels and quality (vertical and temporal).

iii. Detailed groundwater investigations through modeling approach (future prediction of flow and solute transport under various stresses) to study the factors which are responsible for the worse groundwater quality and declines in levels.

iv. Installation of treatment/recycling plants for sewerage and industrial effluents as well as for solid waste in the city at appropriate locations.

v. Pumping tube wells should be installed after assessment of aquifer potential and should be scattered uniformly and possibly near a

recharge source.

vi. Water saving campaign through public awareness and giving subsidy on water saving instead of water supply.

vii. Artificial recharge / Rainfall harvesting through rainfall-runoff modeling at identified potential sites and to explore more feasible sites in parks, playgrounds and other natural depressions.

viii. Regular monitoring and lining of surface drains in city area.

ix. To maintain minimum flow in Ravi river for dilution of pollutants and enable it to act as source of recharge.

x. Construction of lake/ponds in the east-west of Lahore to recharge the aquifer after detailed investigations.

xi. Explore possibility of Lahore Brach Canal and BRBD canal as recharge sources.

xii. Concept of earthen green belts/dividers along the roads should be adopted from where rainfall water can leach down naturally or some injection wells can be installed as deemed appropriate.

7. ACKNOWLEDGEMENTS

The work of this paper has been carried out by Physics Directorate of Irrigation Research Institute (IRI) under a Provincial Government funded project on artificial recharge. Cooperation extended by different provincial, federal institutions/departments is acknowledged. The team of scientist who has been working day and night to collect the data and analyze the same is a collective effort and wisdom without which this work would have not been completed.

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Research Article

Analysis and Treatment of Tannery Waste Water by using Combined Filtration and Coagulation Treatment Process

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Abstract: Tannery waste water severely effects the quality of water bodies into which it is discharged. Tanning effluent contains organic matter, chromium (Cr) and solid waste such as fleshing, trimmings, shavings and buffing dust. About 60% of the total chromium salts react with hides while 40% of the chromium amount remains in the solid and liquid wastes, which makes it a potential environmental concern. In this research work, tannery waste is processed by the pre-treatment step using a filter media followed by post treatment coagulation process. The later step is analyzed using $FeCl_3$ as a coagulant by varying chemical dose and settling time. These parameters were optimized to maximize the pollutant removal efficiencies measured in terms of reduction in concentration of Cr, total dissolve solids (TDS), total suspended solid (TSS), turbidity, biological oxygen demand (BOD_5) and chemical oxygen demand (COD). It was observed that by using 150 mg/L coagulant dose with 24 hours settling time, maximum removal efficiency of 93 % Cr, 71 % TDS, 95 % TSS, 72 % turbidity, 81 % BOD and 85% COD was achieved. The hybrid treatment process, investigated experimentally, can be employed commercially as a pre-treatment step for tannery waste waters.

Keywords: Tannery waste water treatment, coagulation, filtration, removal of chromium, effluent treatment, treatment process

1. INTRODUCTION

Due to increased population growth there has been an increase in the number of industries to meet the day to day demands of the mankind. Along with the useful products, these industries generate a large amount of toxic materials in various forms of solid, liquid and gaseous contaminations. The quantity and toxicity of these hazardous releases vary and depends on the type of industries. In 1991, Sehn et al. [1] analyzed that among all the industrial wastes, tannery effluents are the top ranked toxic releases. A significant part of the chemicals used in leather processing is not actually absorbed or consumed in the process and hence it is discharged into the environment. Due to industrial enlargement, huge amounts of industrial wastes are accruing in the environment and can't be disposed [2]. Liquid effluents from light leather processing comprises about 10 to 100 mg/L of organic matter, chromium, sulphide, and solid waste including fleshing, trimmings, shavings and, buffing dust [3]. About 60% of the total chromium salts react with the hides and about 40% of the chromium amount remains in the solid and liquid wastes [4]. Bidut et al. [5] investigated that Cr is hazardous to human wellbeing, beasts and the surroundings. Nowadays, all tanneries should thoroughly ascertain their waste watercourses. In Pakistan, there are a large number of tanneries (registered as well as un-registered) and footwear manufacturing units. The increase in the number of tanneries can be attributed to the increased demand of tanned leather in the world markets till the end of the fiscal year 2007-08.

Tanning involves a complex combination of mechanical and chemical processes. The heart of the process is the tanning operation itself in which organic or inorganic materials become chemically bound to the protein structure of the hide and

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preserve it from deterioration. These tanning agents give rise to the two predominant types of tanning operations- chrome and vegetable tanning. The pre and post tanning procedure in both tanning process is nearly the same but the difference is in the actual carrying of the tanning operations. In chrome tanning operation, the skin is treated with substances like chromium salts ($Na_2Cr_2O_7$, $K_2Cr_2O_7$, etc.) while in vegetable tanning extracts from the bark of various trees are used as the tanning agents.

The objective of any tannery waste water treatment is to reduce the organic matter, solids, nutrients and other pollutants such as BOD, COD, TSS, TDS and Cr to adhere the discharge standards limits set by relevant authority as allowable level of pollutants. Waste water treatment methods can be broadly classified as physical- chemical and biological processes [6]. Treatment of tannery effluent is difficult and represents a serious environmental and technological problem due to the presence of a series of chemicals with low biodegradability. So the treatment of tannery effluents is a matter of great concern in the country having leather tanning industry. As a result, a number of researchers have worked on the treatment of tannery effluents using different technologies [6]. Several studies have been carried out for the treatment of industrial effluents through coagulation and flocculation process [7, 8]. Coagulation is typically employed as a pre-treatment process and thus further treatments such as biological (secondary) and advanced (tertiary) treatment are required in the leather industry in order to meet the proposed tannery effluent standards [7]. In 2009, Apaydin et al. [8] introduced the electro-coagulation process that gave removal efficiencies of ~46% COD, 90% sulphide, 97% total chrome and 70% suspended solids. Advanced oxidation processes are effective in oxidation, de-colorization and degradation of organic pollutants but their drawback is of high operating cost compared to the other physico-chemical processes. Tasneem and Virupakash [9] treated the tannery waste water by natural coagulants such as *Cicer arietinum* (Chickpea), *Moringa oleifera* (Drumstick seeds) and Cactus which are relatively cost effective compared to the use of chemical coagulants. They obtained optimum dosage of *Cicer arietinum, Moringa oleifera* and cactus to be 0.1, 0.3 and 0.2 gm/500 mL and maximum reduction in turbidity 81.20%, 82.02% and 78.54% and in COD 90%, 83.33% and 75%, respectively.

The inorganic coagulants are compounds that break colloidal suspensions and help the floc formation. The frequently used coagulants in tannery effluent treatment are:

- Alum: industrial aluminum sulphate $\{Al_2(SO_4)_3.18H_2O\}$
- Iron sulphate ($FeSO_4.7H_2O$)
- Iron chloride: industrial ($FeCl_3.6H_2O$)
- Lime: industrial calcium hydroxide $\{Ca(OH)_2\}$

Among the commercially employed coagulants, such as $FeCl_3$, alum, lime, and TiO_2, the coagulant TiO_2 at a dosage of 150 mg/L has been reported to yield a removal efficiency of BOD 78%, COD 90%, TSS 100%, and Cr 94%. However, TiO_2 was reported to be not very economically suitable coagulant [10]. Conversely, $Al_2(SO_4)_3.18H_2O$ and $FeCl_3$ produced the least amount of sludge in comparison to $Ca(OH)_2$. Tannery effluents have also been treated with commercial grade lime [11]. Low values of COD and the removal of chromium, TSS, TDS were observed in this investigation. In this research work, untreated tannery effluent was treated by a combined process of settling, filtration and coagulation with $FeCl_3$ adopted from [12].

2. MATERIALS & METHODS

2.1. Experimental Setup

The experiments were carried out on a lab scale coagulation and flocculation unit with a pre-treatment filtration step. The Fig. 1 and 2 show schematic of the process and equipment that was employed in this work.

2.2. Experimental Procedure

First, 5 liters waste water was passed through the filter media in a pre-treatment step in order to reduce the solid content from the tannery effluent. The filtrate was then passed through the chemical treatment step in a coagulation and flocculation unit. $FeCl_3$ coagulant with a dose of 100 mg/L,

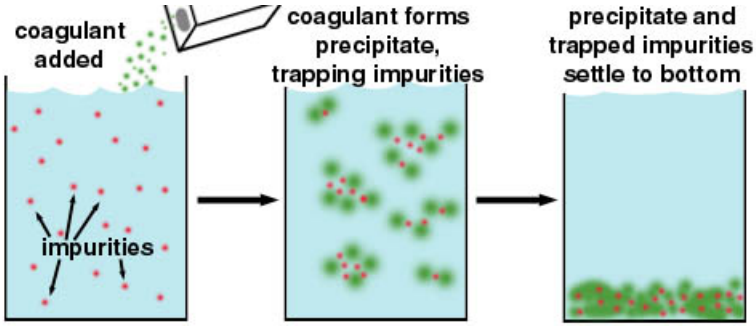

Fig. 1. Schematic of coagulation process [7].

Fig. 2. Experimental setup consisting of coagulation and flocculation unit.

150 mg/L and 200 mg/L was added to the filtered effluent and stirred gently for 20 min at 90 rpm. The effluent was then allowed to settle for 12 hours and 24 hours. After settling the supernatant liquid were then analyzed for various physico-chemical parameters such as concentration of Cr, TDS, TSS, turbidity, BOD_5 and COD.

1.3. Analysis of Physico-Chemical Parameters and its Value for Tannery Effluents

Table 1 shows the standard methods of Water and Wastewater (APHA-AWWA-WPCF, 1998) to analyze the pollutant parameters and their values for tannery effluents, treated in this research work.

2. RESULTS & DISCUSSION

Jar tests were performed by using the $FeCl_3$ coagulant. At the end of each test, the amount of residual pollutant and % removal efficiency of each parameter was measured in order to find out the optimum coagulant dose and settling point.

Table 1. Method of analysis and values of physico-chemical parameters for tannery effluents.

S. No	Parameters	Method of Analysis Used	Values of Tannery Effluent
1	Chromium	Colorimetric Method	725 mg/L
2	TDS	Gravimetric Method	8575 mg/L
3	TSS	Gravimetric Method	2395 mg/L
4	Turbidity	Digital Nephelometer	1500 NTU
5	BOD_5	Microbiological Titration Method	720 mg/L
6	COD	Closed Reflux Colorimetric Method	1150

Table 2. Analysis of coagulant dose and settling time for % removal efficiency of pollutant.

Dose (mg/L)	Settling Time (hr)	% Removal Efficiency of:					
		Cr	TDS	TSS	Turbidity	BOD_5	COD
100	12	69	60	90	50	51	61
100	24	78	62	91	50	55	64
150	12	91	69	94	71	78	83
150	24	93	71	95	72	81	85
200	12	80	62	92	60	59	72
200	24	88	63	93	62	63	74

Table 2 shows the % removal efficiency of the pollutant residues in the tannery effluents by using the coagulant dose of 100 mg/L, 150 mg/L and 200 mg/L for settling time of 12 and 24 hours.

Fig. 3 and Fig. 4 shows the % removal efficiency of the pollutant vs coagulant dose for settling times of 12 hours and 24 hours. From these figures, it can be observed that by increasing the dose, % removal efficiency increases up-to 150 mg/L but after this point dose had an inverse relation on the treatment process. The reduction in treatment efficiency, due to increase in dosage beyond 150 mg/L, may be attributed to increased number of coagulant particles surrounding the hazardous waste particles hindering their combination and of formation flocs that may settle easily [12].

Furthermore, it was observed that the settling time had a direct relation with the treatment process, i.e. by increasing the settling time the efficiency of the treatment process increased and vice versa. Fig. 5 shows the treated results of different parameters by the proposed process and the value of these

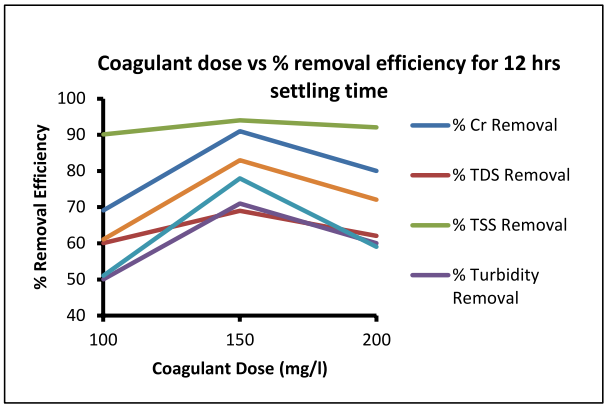

Fig. 3. Effect of coagulant dose on % removal efficiency for 12 hours settling time.

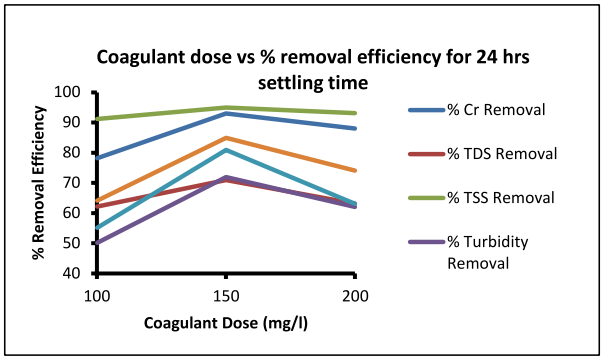

Fig. 4. Effect of coagulant dose on % removal efficiency for 24 hours settling time.

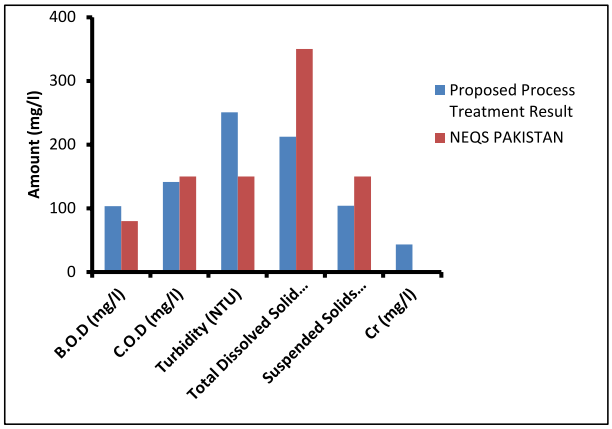

Fig. 5. Comparison of parameters by proposed hybrid treatment process and NEQS.

parameters outlined by the National Environmental Quality Standards (NEQS) of Pakistan.

The treatment results confirmed adherence of most of the parameters for treated waste water, through proposed hybrid treatment process, with the NEQS of Pakistan. However, it is worthwhile to note that BOD_5 after treatment was observed to

be slightly higher than the desired level, i.e., 80 mg/L as specified by NEQS of Pakistan. Similarly chromium content of the treated effluent was also higher than the desired 1 mg/L specification. Based on the experimental results it may be concluded that the proposed hybrid treatment process can serve as a suitable and effective pre-treatment step and only additional processing to remove remaining chromium would render the discharge of tannery waste water safe and environmentally more benign.

3. CONCLUSIONS

From this research it is concluded that the proposed hybrid treatment process (filtration and coagulation) can be used as an effective pre-treatment step to treat tannery waste waters. The increased $FeCl_3$ coagulant dose from 100 to 150 mg/L, increased the removal efficiency of the pollutants. However, any increase above the 150 mg/L resulted in decreased removal efficiency due to hindrance in floc formation of waste particles. Hence the 150 mg/L was identified as an optimum value and is thus suggested for the longer settling time of 24 hrs. The results obtained with the use of these identified optimum values suggested that this process was able to achieve the maximum % removal efficiency of 93 % Cr, 71 % TDS, 95 % TSS, 72 % turbidity, 81 % BOD and 85% COD. The results obtained are in good agreement with NEQS except of BOD_5 , turbidity, and chromium content. Therefore, post-treatment would be required to reduce chromium content to <1 mg/L as required by NEQS of Pakistan.

Nomenclature:

Cr	Chromium
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
BOD_5	Biological Oxygen Demand on day 5
COD	Chemical Oxygen Demand
NTU	Nephelometric Turbidity Unit
NEQS	National Environmental Quality Standards
mg/L	milligram per liter
rpm	revolution per minute

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Research Article

Strategy to Develop Knowledge-based Second Opinion Health System

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Abstract: Healthcare expenditures rise day by day. There is a clear disparity among nations to provide global healthcare and equal health facilities among different countries. This research aims to develop a knowledge-based online second opinion health care management system and develop a methodology to receive quality health care advice without traveling abroad. By using a knowledge-based expert opinion system, a subscriber or patient can easily get a second opinion and evaluate a first consultation or opinion provided by the current doctor to any doctor practicing in any distant location and review complete case information. Knowledge-based healthcare system specifically focuses on an online portal designed to provide connectivity between patients and healthcare specialists, clinics, or hospitals. There is an objective of provisioning of expert medical second opinion for patients from registered care consultant or care facility. Patient has the liberty to select one or more than one appropriate consultant(s) on the basis of their profile, ranking, and reviews. Defined set of cost is fixed by the consultant(s) for medical consultation from specialty dashboard with the ability of communicating complete case information, along with first opinion by their primary consultant and level of urgency for getting the opinion back from care consultant.

Keywords: Knowledge base health, universal healthcare, care consultation, second opinion system

1. INTRODUCTION

Healthcare conditions of the peoples around the globe are amazingly different. One part of the world, which is technologically advanced, provides top quality care to its people [1]. On the other hand people living in poor third world countries have no access to better healthcare. They cannot even afford the cost of healthcare services in western developed countries. The cost of care is so high that it is not affordable for masses living in developing or underdeveloped countries [2]. Think tanks, government agencies, organizations, employers and insurance companies all are working on the grave issue to provide better healthcare to all human beings all over the globe to save human lives and build a better world for everyone on the planet [3]. Compared to developed countries in Europe and America, the situation in Africa and certain Asian countries is totally different, i.e., where physician to patient and hospital bed to inpatient ratio is even less than 1 per 1000 patients respectively. Healthcare, care providers and care delivery centers, all are not available to masses [4]. Governments have inadequate funds to spend on healthcare and humans are losing their lives due to unavailability of care and its centers [5].

Countries have two basic models of providing healthcare to their people, where one is private like in countries such as USA and the other is government supported where it is state-funded system and government is responsible to pay the bills, i.e., Canada, UK. Both the models have their

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own advantages and limitations [6]. Care disparity which exists between developed and developing countries has been the issue of research where collaboration of policy makers, researchers, and civil society, controlled by officials, is required with merger of political, academic, and support experience [7]. This approach is do-able but requires lots of collaboration among all players of the healthcare and bureaucratic circles which is not very simple and hence causing not to happen. The new approach is to use internet as a medium to bridge the gap between care quality and cost for developing and developed countries.

2. CARE DISPARITY

Physician services, consultations, and hospitals are the main sources of healthcare spending that rose much faster than the growth rate of medicine spending. In USA, healthcare expenditures rising faster than inflation and wages inspite of several initatives taken to control them [8].

Health care spending in USA increased to 5.3 percent in 2014 in comparison to a growth of 2.9 percent in 2013. Total spending on healthcare in 2014 reached to around $ 3.0 trillion which equals to $ 9,523 per person per year. This expenditure on healthcare contributes to 17.5 percent of GDP which is up from 17.3 percent in 2013 [9]. The same growth is expected in the US healthcare and by end of 2016, it will become almost 18% of the GDP of the country [10]. US healthcare spending when categorized by type of sponsor is mainly contributed by the following top four players where households contributed 28 percent, private business contributes 20%, federal government contributed 28% whereas local and state government fund 17 percent [11]. Experts agree that the increase in expenditure in recent years was primarily due to the Affordable Care Act under which major coverage expansions are planned and promoted, particularly for Medicaid and private health.

On the other side, 182 million population of Nigeria is at risk of Malaria. It is transmitted throughout the country. Malaria accounts for almost 60% of outpatient and 30% of hospitalizations in Nigeria. It is highest cause of mortality of children under five and contributes to about 25% of infant mortality and 11% of maternal mortality. Furthermore, 12 percent of the world's population lives in the African region and has the world lowest life expectancy rate, i.e. 58 in females and 55 in males. Africa also has the highest adult mortality rate of more than 330 per year in 1000 humans [12].

One in every 10 South Africans is HIV-positive out of a total 54.96 million population. The estimated

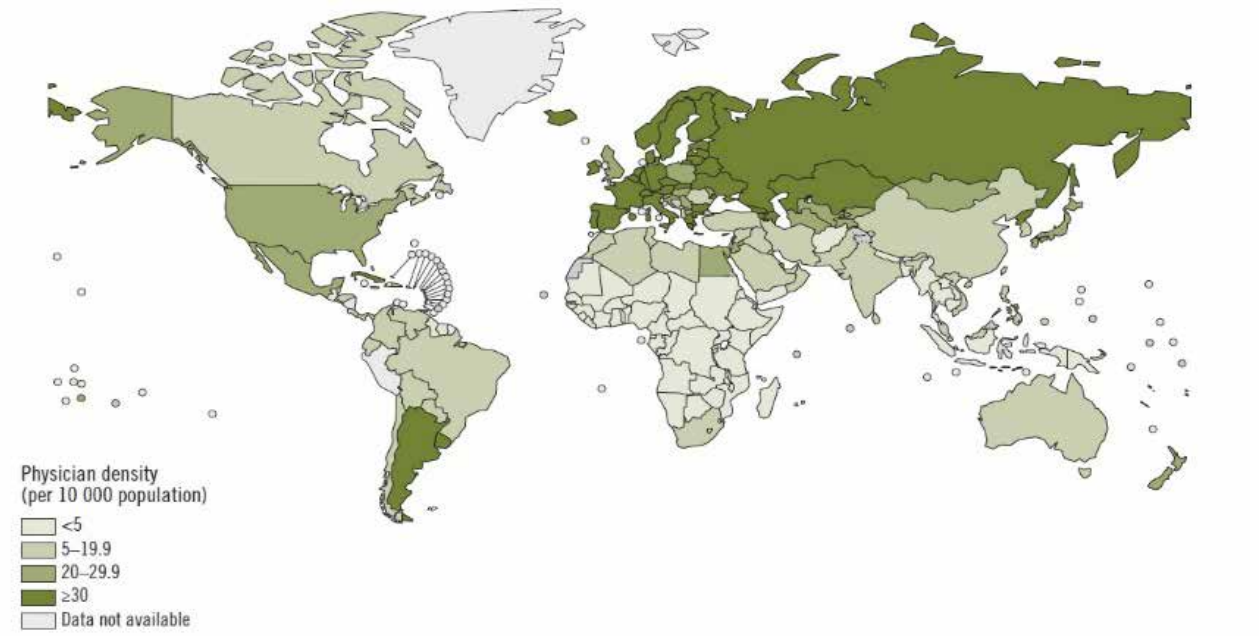

Fig. 1. WHO, "Core Health workforce and infrastructure (density per 10, 000 population) Health Workforce Density Report," 2015 [14].

Table 1. Physicians available per 10,000 persons and GDP spending.

Region	Physician Density Value (2007-13)	% of GDP Spending (2012)
African Region	2.7	5.6
Region of the Americas	21.5	13.6
South-East Asia Region	5.9	3.7
European Region	32.1	8.9
Eastern Mediterranean Region	12.7	4.6
Western Pacific Region	15.5	6.6

overall HIV occurrence rate is around 11.2% of the total population. In 2015, the estimated population will be 6.19 million living with HIV. Research also reveals that an estimated 16.6% of population is HIV positive among adults aged between 15 to 49 years [13]. Niger has 0.02 Physicians density per 100 population which means there will be only 2 providers/physicians for a population of 0.1 million people. In Fig. 1 the data shows physician density around the world.

In another perspective, with respect to regions, the Physician density per 10,000 humans according to WHO region as well as the percentage of GDP spending across the world is as follows:

One can conclude from the above Fig. 1 and Table 1 that there are two major problems which the world is facing at the moment to increase healthcare services for human beings on Earth and which are as follows:

1. Cost
2. Health infrastructure

a. Physicians are core component of that infrastructure

b. Inpatient facilities

c. Outpatient facilities

Researchers believe that almost 40% of patients take a second opinion after getting primary consultation from a doctor [15]. Introducing cost effective and quality healthcare, might serve the purpose, but the problem for developing countries of the world won't be solved, so that requires developing some methodology which should be able to address this challenge in a more effective and efficient way.

A new approach is proposed to address the problem by creating a unified portal where patients can register to portal free of cost for taking online care from the registered physicians/consultants. Medical professionals and consultants can only register to portal by passing the strict verification process of their diplomas, certificates and professional licenses at zero cost.

3. RESEARCH APPROACH/ METHODOLOGY

Secondary data have been being used to evaluate the potential of existing systems with respect to their functional enrichment to satisfy the user needs along with their usability from end user/patient perspective. Qualitative analysis technique is used to design a new online system to help facilitate the physicians/consultants to provide appropriate care consultation to patients from all around the world by consulting the patient medical records along with diagnostic and/or monitoring orders and extract an expert opinion which will include further treatment suggestions or substitutions and recommendations regarding future wellbeing considerations.

3.1 Review of Existing Work

Usually Specialty Consultations can be initiated by a patient or by a physician. If a patient/subscriber is demanding a healthcare consultation, the patient usually has to involve his or her local treatment provider. Once the patient and the patient's physician agree to follow the consultation route, the physician registers with the available online services. All such existing services usually accept mail history

information of the patients.

The provider, being the technical hand, then completes a patient history and attach the necessary imaging and lab results by post to the consultants address. A specialty consultant reviews the case, as described by the referring physician, within three to four business days. After the primary evaluation has been re-evaluated by the Specialist consultant, a second opinion is generated and sent back to the patient's primary physician. Patients are notified through the email for the completion of opinion process.

We take a two way approach to analyze the existing systems and their functionalities to find out the limitations in their approach relevant to second opinion healthcare service which are as follows:

1. US patents/prior acts
2. Online systems.

3.2 US Patents/Prior Acts

We have studied almost all the patents and patent applications available to date on topics relevant to second opinion healthcare consultation from the USPTO database [16]. The descriptions and details of the patents and patent applications helped us to understand the limitations in the existing approaches as shown in Table 2. Each existing system/patent/ application is evaluated on certain features which are found to be necessary for such systems.

e-Cleveland's "MyConsult" offers an online medical second opinion service that connects the patients to a consultant physician. These special expertise and services are offered to patients when they are facing a serious diagnosis at predefined/ fixed costs. An in-depth review of medical records, patient history, laboratory, and imaging results leads the Cleveland Clinic experts to render an expert second medical opinion which may include treatment choices or substitutes, as well as endorsements regarding future healing considerations [17].

Partners Online Specialty Consultations is a service for patients to get second opinion where patients and consultants, referring providers can register online to the system. It requires patients to send their pathology and radiology reports by paper submission through post [18]. A Gynecologist's Second Opinion Online is an online second opinion/consultation book which is highly focused on gynecology specialty [19]. Another study proves that patient is more satisfied once second opinion is sought with some other consultant but this study is more focused on cancer patients. Ultimate beneficiaries of the service are patients but the service and request can only be triggered by providers [20].

4 PROPOSED FRAMWORK FOR ONLINE SYSTEM

The Institute of Medicine stated "the free flow of information" and "the patient as the source of control" as key features of patient-centered care [21]. Preceding studies have stated that 90 percent of the patients would prefer to communicate via email with their treating providers or primary care physicians. 56 percent of the patients specify that it may affect their choice of treating doctor [22].

Most of the studies revealed that the availability and utilization of second opinion services are always cost effective along with a considerable clinical impact [23, 24].

A more user friendly system will be designed by keeping the focus on enhancing patient care options through enabling new ways of access between patients and healthcare providers/consultants from any part of the world. The knowledge base online second opinion medical consultation service will enable patients and its users to stay at home country and get access to the world's best specialists to provide the best skilled care assistance and advice for patient's current problem to bridge the gap of expertise needed for the delivery of top class care.

The abstract system model presented below illustrates the steps involved in the implementation of system for a more robust and user friendly system to facilitate the second opinion process. However, it should be clearly understood that the workflows discussed and designed only present the preferred embodiment of the system for the purpose of design and that the numerous modifications, enhancements can be made to them keeping the core concept intact.

The core focus of the new system should be on the following main areas to overcome the current

limitations in the available systems:

1. Usability.
2. Ease of use and user friendliness.
3. Patients should have a choice of consultants to take opinion from for their care.
4. Patients can rank a consultant's advice.
5. Patient can view the consultant's:
   a. professional background
   b. qualifications
   c. affiliations
   d. attachments
6. Patients and consultants must have an easy to use messaging system.
7. Messaging alerts generation for the interactivity among the system users should be a must.
8. Consultants must have a choice to update their cost of consultation on the basis of their ranking by the patients.
9. System should provide a universal accessibility to the users and at any time.
10. System should also provide universal subscription of patients at any time from any where.
11. System should also provide universal subscription of consultants at any time from any where.
12. Patients should be able to post their comments/ reviews on consultant's consultation/opinion.
13. System should provide a specialty dashboard to patients from where they should easily select the specialty relevant to their case.
14. Specialty dashboard should provide the lists and details of all the hospitals, clinics, consultants available/registered for that specialty so that patient can select the best for his case to have opinion from.
15. Patients should have an easy to use mechanism for the uploading of their pathology and radiological reports.
16. Patients should have an easy to use mechanism to state their stories for the consultants in their words.

Fig. 2 illustrates system workflow and details are discussed below.

Fig. 2 is an abstract system component diagram which shows interactivity at a very high level. The system is composed of 3 main access blocks, on the basis of type of member accessing the system:

a. Member-patient block;

b. Common knowledge based second opinion block; and

c. Member-Consultant block.

1.1 Member-patient block comprises of entities that will help member type patients to use the system to get the required consultation from consultants and is further subdivided into the following five modules:

1.1.1 Member-patient registration

1.1.2 Member-patient specialty dashboard

1.1.3 Member-patient case management

1.1.4 Member-patient communication

1.1.5 Member-patient reviews

1.2 Member-consultant block comprises of entities that will help member type consultants to use the system to provide their advice to patients who assigns their cases to them and is further subdivided into four basic modules.

1.2.1 Member-consultant registration

1.2.2 Member-consultant patients

1.2.2.1 Member-consultant patients provides access to patients who have assigned any cases to the logged in consultant and is subdivided into two sub modules

1.2.2.1.1 Member-consultant-patient communication module

1.2.2.1.2 Member-consultant-patient case management module

1.2.3 Member-consultant account management

1.2.4 Member-consultant reviews

1.3 Common is the common area in Fig. 2 which is the core of the whole system and provides a mechanism to consultants to provide their advice/opinion on the basis of medical

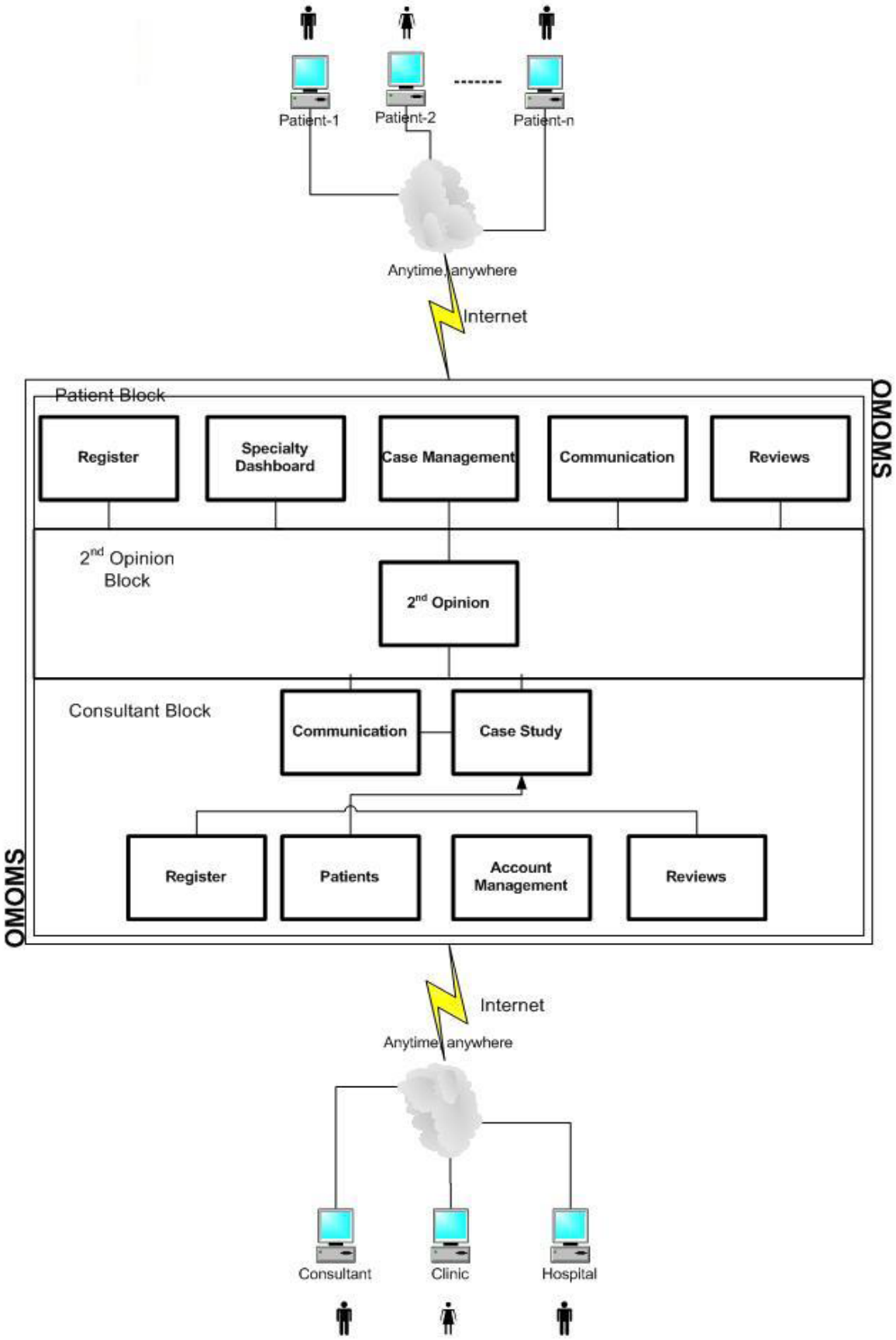

Fig. 2. Proposed mechanism for online healthcare management system.

information provided by the patients. Patients can access the respective opinion/ advice from the assignee consultant from their member functionality area after logging into the system.

1.4 Fig. 2 also provides internet as the medium to access and use the system functionality for the member types i.e. patients, consultants

1.5 Fig. 2 also provides a clue that n-patients can access the system at anytime from anywhere through the internet.

1.6 Fig. 2 also provides some clue for member-consultants as they can be the part of system as individual or be as clinic or hospital to serve the patient requirements.

1.7 Fig. 2 does not provide any details of the administrator's access mechanism and their respective functionality blocks which will be used to manage the knowledge based second opinion health management system.

The research not only took into account the modeling of the system but also considered making the system feasible for patients and physicians and its sustainability from operational perspective.

4.1 Patients Access

According to UN Broadband Commission, 57 percent of the world's population remains offline and is not able to take benefits of the huge economic and social advantages of the Internet [25]. The usual Internet adoption rate in poor countries lies below 10% in 2013, which is less than 1/4 of the espousal rate in developing countries and 1/8 of that in developed countries [26].In developing countries where the system will get implemented and facilitate the patients the access to internet is made available by internet cafes. Internet cafes are usually available to people in low income areas of the society where they can access the internet on a per hour rate. Similarly the mobile internet is also becoming very cheap now a days, so a mobile version of the application will also become helpful for the users of developing countries to cheaply access the application.

4.2 Physicians Access

Physicians as the integral component of the system will also be needed to join the portal to provide their valuable consulting services. Physicians will be able to sell their consulting services on the portal and patients will rank them by the value of their consultation. More the number of patients, more will be the physicians available to provide their service. An automatic provider evaluation system will be added in the application that will rank providers from 1-10 on the basis of their qualification, satisfied patients population and their professional associations.

4.3 System Support

The application will require lots of storage space to host the patients' health related information which will not only include their history but will also include imaging results. The system will get benefited by charging a small portion of physician fee that will not be more than 2%. System is designed with a noble cause and it will only require sustainability for its operations. Online help will be made available to patients and providers through frequently asked questions and via send an email function.

5 CONCLUSIONS

The provision of knowledge-based decisions support second opinion consultation while evaluating first consultation report along with the capability of allowing consultants direct registration and their ranking mechanism by the patients who have taken any kind of second opinion, is the need of the time.

Furthermore, the aforementioned analysis concludes that the availability of such system will help achieve cost effectiveness which results in lowering the healthcare budgets which is the biggest challenge to the growing economies of the world. We need to market the use of such system so that maximum people should make use of such systems to avoid un-necessary treatments or surgical procedures that will result from highly expert opinion.

The availability of a universal portal where patients from all over the world can register along with the registration of consultants from reputable institutes/clinic/hospitals, is the need of the time and will bring effective care to the patients residing in

such areas of the world where care expertise is not available.

In theory, a new idea has been surfaced through the current research by building a universal portal over the internet to be accessed by the patients around the world to get benefited from the expert's opinion. The current research will open a new era for researchers to think and work in a direction to improve ways of care coordination between patients and physicians. Improved, easily accessible, fast and cost effective ways of care coordination should be the next areas of research.

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Research Article

Crop Growth Monitoring using Green Seeker Technology - A Case of NARC Field Station in Pothwar Region

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Abstract: The green seeker technology was applied to acquire Normalized Difference Vegetation Index (NDVI) and Red-Near Infrared (NIR) ratio of main crops i.e. wheat, rice and oats grown in the NARC field station, Pothwar region to provide repository for future monitoring of the crops through satellite imaging. The spectral data of different growth stages of the wheat crop indicated NDVI values ranging between 0.1 - 0.88 during Rabi 2006-07 and Rabi 2015-16. The values of wheat and oat crops indicated a similar pattern during Rabi 2015-16, but with slight difference before the heading and near the harvesting stage of the crops. The NDVI values of rice crop grown in the irrigated fields during Kharif 2007 ranged between 0.03 - 0.61. The value was maximum during the heading followed by maturity stage. NDVI values observed in the rainfed fields indicated high variability due to heterogeneous crop cover resulting from variable moisture conditions, fertilizer use, soil type and sowing practices. A detail study needs to be carried out in different agro-ecological regions of the country to collect unique spectral characteristic of different crops and the surrounding land covers to support satellite based crop monitoring and yield forecasting in future.

Keywords: Green seeker, spectral reflectance, vegetation index, crop monitoring, Pothwar

1. INTRODUCTION

The economic base of Pakistan relies on optimum growth and development of the agriculture resource in the country. There is a need to adopt technologies that can lead to effective monitoring and assessment of this resource in advance. Satellite imaging provides a synoptic view of a large earth's surface area for resource monitoring which is by other means difficult to monitor or at times impossible to access. Since chlorophyll, a key indicator of crop physiological status, has strong absorbance peak in the red spectral region, empirical models of predicting chlorophyll status from spectral reflectance are largely based on red spectra [1-4]. Under normal conditions, nitrogen fertilizer influences chlorophyll concentration in green leaves [5]. Image from the green and near infrared (NIR) bands highlight the amount of vegetation and give an indication of plant vigor. Visible and infra-red (IR) wavelength bands (channel) on the satellite multi-spectral sensors allow monitoring conditions like greenness of plants, drought and desertification.

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The differences in leaf color, texture, shape or even how the leaves are attached to plants, determine, how much energy will be reflected absorbed or transmitted. The comparison of the reflectance values at different wavelengths, called a vegetative index, is commonly used to determine plant vigor. The most common vegetative index is the Normalized Difference Vegetation Index (NDVI), the value of which helps identify areas of varying levels of plant vigor within fields on an image. The NDVI data have been used extensively in vegetation monitoring, crop yield assessment and forecasting [6-8]. The index works on the phenomena that growing green plants absorb radiations in visible region and emits infra red radiations. The reflectance of vegetation cover especially the health of crop cover can be determined using the Green Seeker (GS) technology which measures NDVI and Red- NIR ratio of the crop cover.

The studies have shown that seasonal crop growth and development can be monitored using vegetation indices (VI) computed from red and NIR wavelengths e.g. [9-11, 5]. Besides the indicators of crop growth variables, VIs were applied to detect nitrogen stress [12-13]. The magnitude and duration of seasonal VI profiles are directly related to leaf area index (LAI), biomass and percent cover [14]. These parameters are largely influenced by variations in soil fertility, soil moisture, planting date and crop density. The potential yield of a crop is said to be a function of leaf area at the beginning of the reproductive stage and final yield is related to the duration of green LAI assuming the absence of significant stresses during the heading/ filling stages. The highest single date correlations between yield and VIs occur around the booting-heading stage of wheat, which is closely associated with peak seasonal VIs [15]. The challenge remains at the farm level to develop more quantitative in-field yield variation and to deliver them in time to effectively influence crop management decision. The primary focus of this study is to develop a repository of spectral reflectance data of crops using green seeker technology that would help in crops yield estimation through multispectral remote sensing in future.

The study area of National Agricultural Research Centre (NARC) lies within longitudes 73º 6´ - 73º 9´ E and latitudes 33º 38´ - 33º 42´ N in Capital territory of Islamabad, Pothwar tract of Pakistan (Fig. 1). It comprises of experimental fields and laboratories over an area of about 565ha along Korang stream downstream of Rawal dam. The climate is sub-humid with mean annual rainfall of about 1216mm (1988-2008 period) recorded at NARC Agro-met. station. Mean monthly maximum temperature ranges between 35-41ºC and mean monthly minimum temperature between 1-25ºC. June is the hottest and January is the coldest month in a year. The soil is deep and varied in type i.e. mainly moderately calcareous clay loam to silty clay loam with good drainage. About 90% area is relatively flat with a general slope of 1% [16]. Major Rabi crops are wheat, oilseed, oats and lentil while Kharif crops are maize, rice and millet. Fodder is usually grown in both the seasons. More often the sowing of various crops especially the winter (Rabi) season crops is delayed due to uncertain and scanty rains prior to sowing of the crops [17].

2. MATERIALS AND METHODS

The Green Seeker instrument equipped with Holland Amber Sensor (Ntech Industries, Ukiah, CA) was used in the cropping fields of Crop Science Institute (CSI) to collect reflectance data of wheat crop during Rabi 2006-2007 and rice crop during Kharif 2007 season (Fig. 2a). This instrument detects electromagnetic bands red and NIR of reflected energy from the material and determines NDVI and bands ratio. The instrument's optical sensor captures and analyzes the light reflectance of plants and the collected data with the sensor can be downloaded to a personal computer in a text format that can be accessed by Microsoft Excel. Later on, a handled green seeker NDVI sensor developed by Trimble's Agriculture Division,USA was used to collect the reflectance data of wheat and oat crops during Rabi 2015-16 (Fig. 2b). Rabi season starts by mid-October in the rainfed areas, but main activity of wheat crop sowing starts from 1st November and continued till 30th November. In some cases when precipitation period delays then late sowing of wheat continues to December.

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

Where

NIR = Near Infrared Reflectance band value

R = Red Reflectance band value

The index is described by a value ranges from -1 (usually water) to +1 (strongly vegetative growth). The NIR and R bands of remote sensing data are usually used to determine NDVI for monitoring crop growth and discriminating vegetation vigor in the image. Field data e.g., plant condition, sowing & harvesting dates, input use and GPS coordinates were collected from appropriate locations (hereinafter: "segments") after specific time intervals to detect growth variation. As the crops grown in various fields have variable sowing dates and varieties so a particular crop type and its full growth period is focused in this study. For each plot 3 to 5 different readings were taken each time. The instrument was placed at about 0.7m above the crop canopy while taking the readings.

Green Seeker Technology and Satellite Imaging

The Green seeker instrument detects electromagnetic bands red and NIR of reflected energy from the material and determines NDVI and bands ratio. The central wavelength of the red and NIR channels of most multispectral sensors such as TM, SPOT and MODIS, on the current satellites, position at 640-660 nm and 800-870 nm [5]. The red-NIR could be used to estimate crop nitrogen stress [10-11, 13]. The Green seeker technology coupled with remote sensing imaging can be utilized effectively for identification and assessment of vegetation covers, crop acreage, health and yield in any area. Remote sensing offers great potential for monitoring and assessment of crop acreage and production. If utilized effectively, quantification of accuracy and precision of regional crop rotation and estimation of yield from remote sensing can be achieved. Interpreting the reflectance values at various wavelengths of energy can be used to assess crop health. The relationship between reflected, absorbed and transmitted energy is used to determine spectral signatures of individual land features. Spectral signatures are unique to plant species. Imaging scanners are available with spectral bands throughout the ultra violet (UV), visible, short infrared (SWIR) or near infrared (NIR), and thermal IR range. As the growing plants turn green in color the chlorophyll in the leaves absorbs the red radiation and at the same time increases the infrared reflectance [18]. Vegetation is easily detectable with the use of red and infrared bands i.e. it can be distinguished from soil and water. The high spectral resolution of RS data is useful in identifying distinct crop covers, forest types, grass, shrub lands, etc. accurately.

3. RESULTS AND DISCUSSION

The NDVI data of wheat, rice and oat crops was collected at various growth stages during Rabi 2006-07, Kharif 2007 and Rabi 2015-16 from the NARC research station. The wheat crop (Wafaq2001) was sown in the CSI field on 8-11-2006 and wheat (Pakistan2013) in plot no. C2 on 25-11-2015. Observations were made considering various phenological phases of the crop. When 10% of the selected plants were in certain phase, that particular phase was considered to be started. If 50% of the selected plants displayed a certain phase, that phase was considered to be in full swing. Similarly, 75% occurrence of a certain phase displayed by the selected plants was considered as completion of that particular phase and the next phenological phase observations were started at their proper time. Thus, next phonological phase is not bound to appear after the completion of the first one.

During Rabi 2006-07, rainfall remained normal and optimum amount of moisture provided conducive environment during germination stage (Fig. 3a). Rainfall occurred during November and December was optimum and fulfill the water requirement at early stage. During February, 2007, rainfall was more than normal that was sufficient to meet the water requirement at shooting stage. Maximum temperature exceeded 20ºC in March reaching 30ºC in April conducive for maturity of the crop. Minimum temperature above 5ºC in February was also favorable for the crop growth. The mean NDVI values collected during different growth periods of the wheat crop ranged between 0.1 - 0.9. The mean NDVI value was maximum in the heading

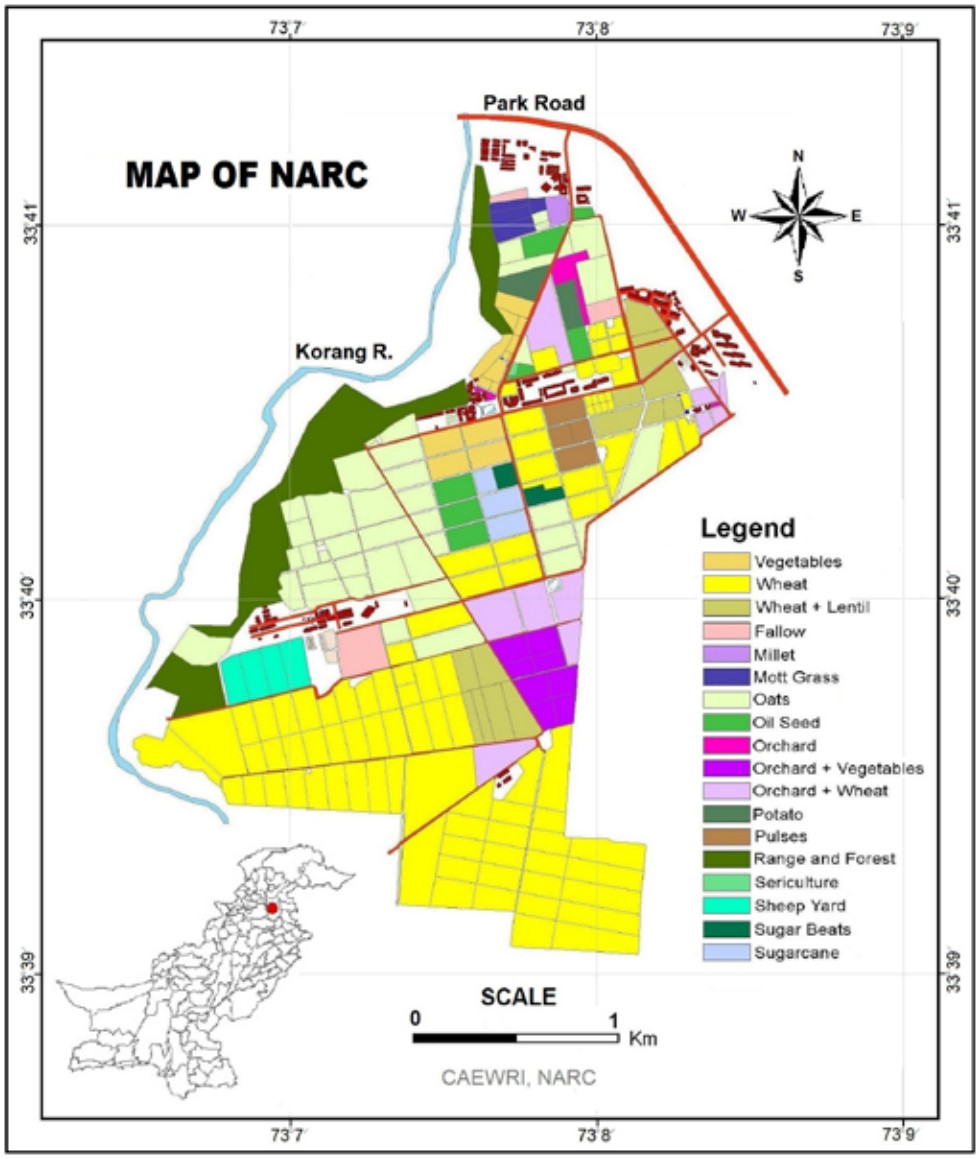

Fig. 1. Location of study area indicating layout of the cropping fields.

Fig. 2a. Handheld Green Seeker instrument for NDVI measurement.

Fig. 2b. A handheld NDVI sensor to assess crop health.

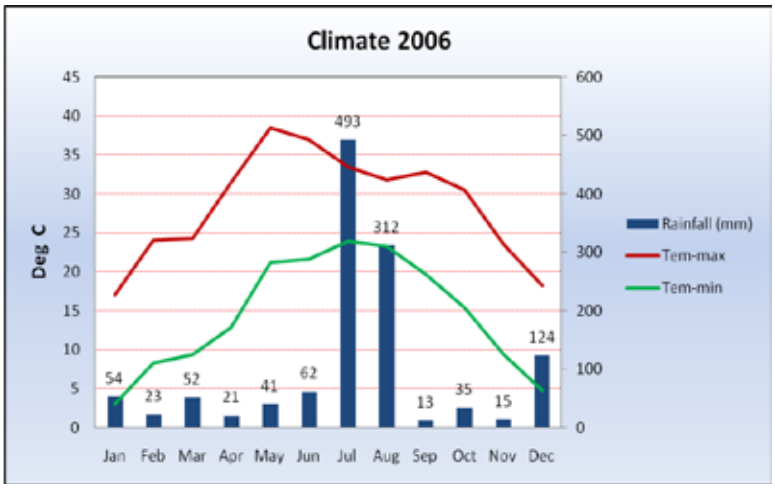

Fig. 3a. Monthly climate data of NARC weather station during 2006.

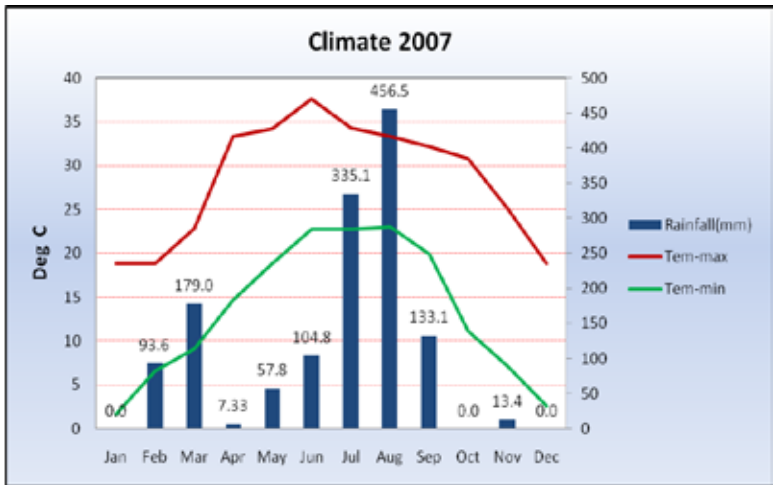

Fig. 3b. Monthly climate data of NARC during 2007.

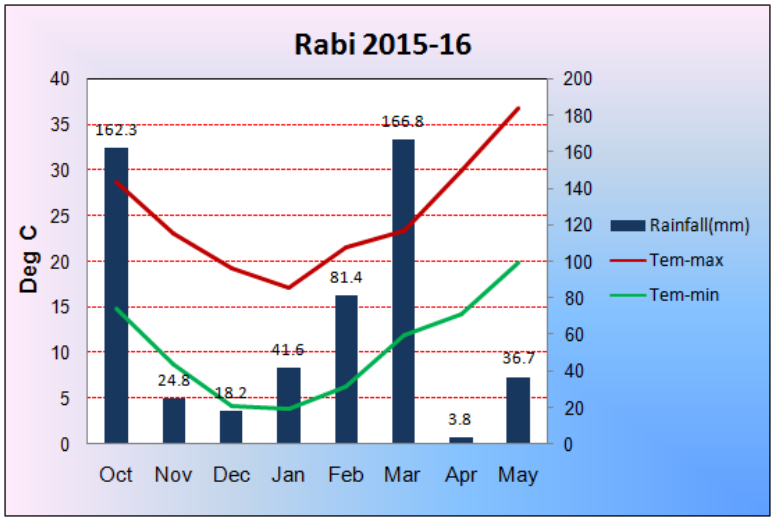

Fig. 3c. Monthly climate data of NARC during Rabi (2015-16).

stage, e.g., 0.88 on 23 February followed by maturity stage of the crop e.g. 0.84 on 30 March (Table 1 and Fig. 4). The least value i.e. 0.12 was on 29 November during the tillering followed by 0.22 on 30 April during the harvesting stage. However, the ratio Red/NIR was found maximum at tillering followed b harvesting stage of the crop. Color infrared gives a good indication of the amount or volume of biomass, therefore lower values of red reflectance reveal vegetation damage or loss. Different growth stages of the wheat crop are shown in Fig. 5.

The rice crop was transplanted on plot no. C4-A on 20-07-2007. During Kharif 2007, the rainfalls of July and August remained above 300mm in Fig. 3b. The maximum temperature of August to October was between 30-35ºC, favorable for rice crop maturity. The mean NDVI values collected through the GS instrument during different growth periods of rice crop ranged between 0.03 - 0.4. The mean NDVI value was maximum on the heading stage while it was minimum during the harvesting stage of the rice crop (Table 2 and Fig. 6). The Red/NIR ratio was found maximum in the tillering followed by maturity stage of the crop. The crop was harvested on 5-11-2007. Different growth stages of rice crop are shown in Fig. 7.

In Rabi 2015-16, NDVI values were again collected of various stages of wheat besides oat crop using a pocket NDVI sensor. The rainfall during Rabi 2015-16 remained normal and optimum amount of moisture provided conducive environment during germination stage of the crops. Rainfall occurred during October was favorable to fulfill the water requirement at early stage of the crop (Fig. 3c). Similarly, February rainfall was also sufficient to meet

Fig. 4. NDVI curve of wheat crop during Rabi 2006-07.

Table 1. Field data of wheat crop collected during Rabi 2006-07.

S. No.	Date	NDVI	Red/NIR	Crop stage
1	29-11-2006	0.12	0.78	Tillering
2	03-01-2007	0.75		Tillering
3	02-02-2007	0.76	0.14	Shooting
4	23-02-2007	0.88	0.06	Heading
5	30-03-2007	0.84	0.08	Maturity
6	30-04-2007	0.22	0.63	Ripening

Table 2: Field data of rice crop collected during Kharif 2007

S. No.	Date	NDVI	Red/NIR	Crop stage
1.	26-07-2007	0.40	0.17	Tillering
2.	20-08-2007	0.32	0.04	Panicle initiation
3.	13-09-2007	0.61	0.12	Heading/flowering
4.	29-10-2007	0.03	0.06	Maturity

the water requirement at shooting stage. Minimum temperature was above 5ºC in February while maximum temperature exceeded 20ºC in February reaching near 30ºC in April. The mean NDVI values collected at different growth periods of wheat crop during Rabi 2015-16 ranged between 0.25 - 0.81 (Table 3 and Fig. 8). The NDVI value was high during heading stage of crop, i.e., 0.8 on 8 March. The least values were observed on ripening stage on 8 December tillering stage, i.e., 0.16 on 26 April and 0.25 at start of the tillering stage. The crop was harvested on 17 May, 2016. Various growth stages of the wheat crop are shown in Fig. 9. Overall, the NDVI data of wheat crop during the Rabi seasons of 2006-07 and 2015-16 exhibited peak values during the heading stage of the crop i.e. mainly in the month of March, indicating full vigor and healthy crop conditions. The variation in values are due to variable time of data taken, crop variety, fertilizer input and irrigation practice. The higher values of crop cover (i.e. exceeding 0.8) also points toward better crop health under favorable climatic conditions during the crop growth period. The relatively lower NDVI values of wheat during Rabi 2015-16 is likely due to rainfed condition in the field that resulted in nominal growth of the crop than the one grown in the irrigated field.

Fig. 5. Different growth stages of the wheat crop during Rabi 2006-07.

Table 3. NDVI data of wheat and oat crops collected during Rabi 2015-16.

S. No.	Date	Wheat	Oats
1	8-12-2015	0.25	0.60
2	9-02-2016	0.42	0.70
3	22-02-2016	0.65	0.76
4	8-03-2016	0.81	0.78
5	11-04-2016	0.60	0.56
6	26-04-2016	0.16	0.37

The oat crop (NARC 2011) was sown on plot no. C4-A on 12 November, 2015. The NDVI values of oat crop during Rabi 2015-16 ranged between 0.37 - 0.78 (Table 3). The NDVI value was maximum i.e. 0.78 on 8 March followed by 0.76 on 22 February (Table 3 and Fig. 8). The least value was on 26 April i.e. 0.37 (maturity stage). The crop was harvested on 11 May, 2016. Various growth stages of the crop are shown in Fig. 10. Overall, the values of wheat and oat crops indicate a similar pattern, but a slight

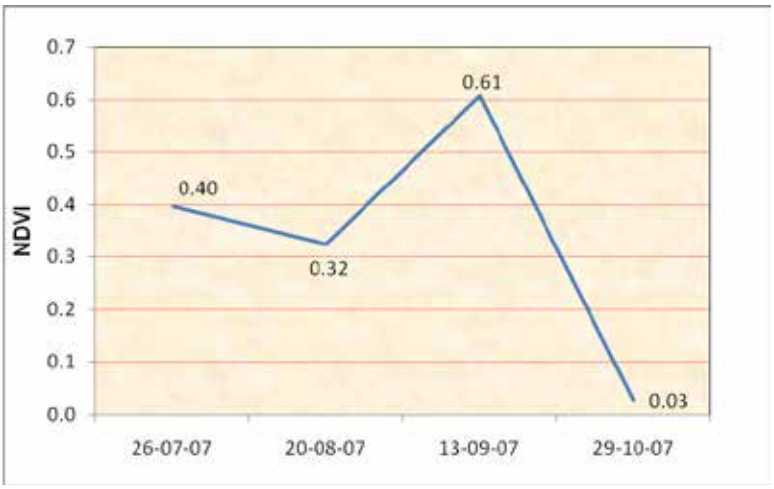

Fig. 6. NDVI curve of rice crop during Kharif 2007.

Fig. 7. Different growth stages of the rice crop during Kharif 2007.

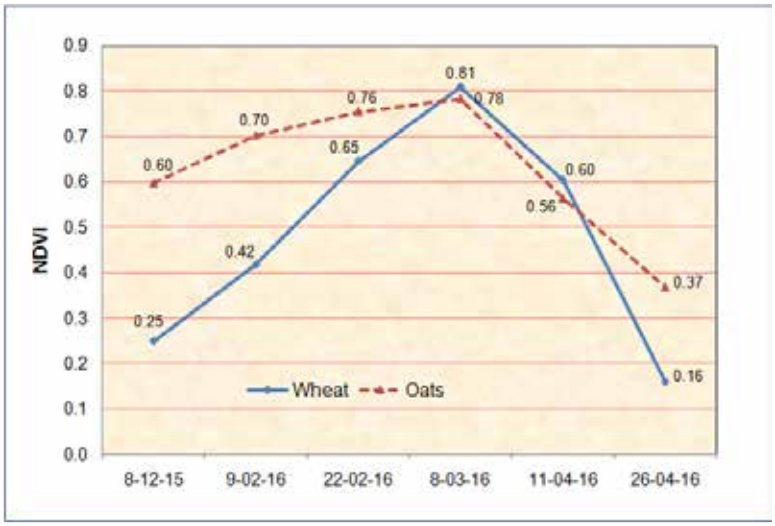

Fig. 8. NDVI curves of wheat and oat crops during Rabi 2015-16.

Fig. 9. Different growth stages of the wheat crop during Rabi 2015-16.

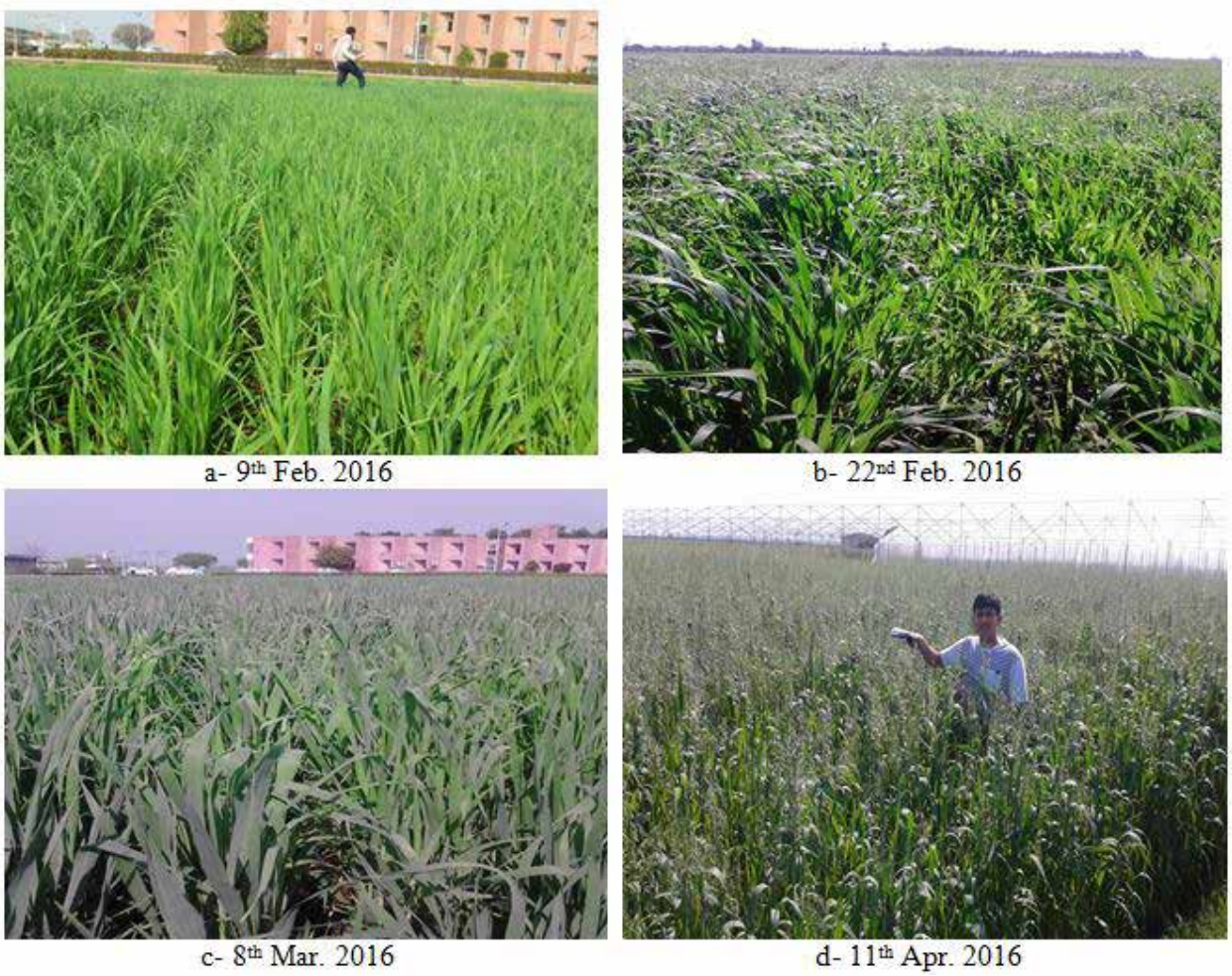

Fig. 10. Different growth stages of the oat crop during Rabi 2015-16.

difference is visible before the heading and near the harvesting stages of the crops. According to Teal et al. [19], the NDVI values are highly correlated with total above ground biomass and crop growth stage is a major factor in predicting yield potential [20]. The NDVI curves of various crops in this study exhibit more or less optimum growth of the crops due to factors like favorable climatic conditions as observed during their growing periods. Raun et al. [20] established a nondestructive estimation of crop yield potential using spectral measurements of wheat crop. This study could provide base for predicting crops yield potential through establishing a relationship between NDVI and grain yield under variable agro-environments.

4. CONCLUSIONS

The spectral data of the wheat crop indicated NDVI values ranging between 0.12 - 0.88 while the values for various growth stages of the rice crop ranged between 0.03 - 0.61 at NARC field station during surveyed periods. The value was maximum in the heading stage likely due to high greenness and plant vigor. Variations in NDVI values were observed in the rainfed fields due to heterogeneous crop cover resulting from variable moisture conditions, fertilizer use, soil type and sowing practices. A spectral repository of various crops and the surrounding land covers needs to be developed for different agro-ecological regions of the country so as to provide base for satellite based crop yield forecasting in future. As crop varieties and climatic pattern are changing regularly with time so it should become a part of long term monitoring programme in the country.

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Research Article

Phytonematode Problems associated with Some Economically Important Plants in Pishin District, Balochistan, Pakistan

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Abstract: Present study was conducted for nematodes communities associated with Pomegranate (*Punica granatum* L.), Grapes (*Vitis vinifera* L.), Peach (*Prunus persica* L.), Plums (*Prunus domestica* L.), Tobacco (*Nicotiana tabacum* L.), Apple (*Malus pumila* Mill.) and Apricot (*Prunus armeniaca* L.) at three localities of Pishin district, Balochistan province. In all investigated plant species twenty nematode species were recorded *viz., Helicotylenchus digonicus, H. indicus, H. pseudorobustus, Hoplolaimus indicus, Meloidogyne incognita, M. javanica, Pratylenchus holdemani, P. penetrans, P. scribneri, P. thornei, Rotylenchus dalhousiensis, Scutylenchus rugosus, Tylenchorhynchus annulatus, T. curvus, T. trilineatus, Tylenchus filiformis, Xiphinema americanum, X. basiri, X. index* and *X. rivesi* from the rhizosphere soil of above mentioned plant species. Among all species, *Meloidogyne incognita* and *Xiphinema rivesi* were dominant. The nematodes problem is rapidly increasing in Pakistan and widely damaging the host range by several species of phytonematodes. This investigation was designed to check the association, soil analysis, nematodes population density, incidence (%) and prevalence of nematodes associated with some crop and orchard plants of Pishin district, Balochistan.

Keywords: Phytonematodes, population density

1. INTRODUCTION

Plant-parasitic nematodes are widespread and are among the most damaging pests of different crops, causing not only severe crop losses of commercial fruits that are meant for export but also seriously limit the production and viability of many other crops. Phytonematodes vary in their feeding behavior; each species causing somewhat diverse type of damage to the crops. Pomegranate (*Punica granatum* L.), grapes (*Vitis vinifera* L.), peach (*Prunus persica* (L.)), plums (*Prunus domestica* L.), tobacco (*Nicotiana tabacum* L.), apple (*Malus pumila* Mill.) and apricot (*Prunus armeniaca* L.) are important fruits and economic crops of Pakistan particularly of Pishin district, Balochistan. Balochistan along with its huge natural resources is one of the rich agricultural zones with great variety of dry and fresh fruits. The province produces 60% percent of peach, pomegranate and apricot, 90 percent of grapes, almond and cherry, 34 percent of apple and 70 percent of date of the total fruit production of Pakistan [1]. The study area (Pishin district) in Balochistan province lies between 30o 04' to 31o 17' north latitudes and 66o 13' to 67o 50' east longitudes. It falls in the tropical agro-ecological zone of bearing a total potential agricultural area

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of 185,280 hectares [2], which is approximately 23.5% of the total geographical area of the Pishin district. Main crops of the district are wheat, barley, cumin, tobacco, apple, pomegranate, grapes, peach, plums and apricot. These plants are affected by many pest diseases but the infection of nematodes in Pakistan, particularly in Pishin district is more serious compared to other developing countries. There is paucity of investigation regarding the host range of nematodes and their damage to commercial fruit species [3].

Pomegranate (*Punica granatum* L.) is an important fruit crop of tropical and subtropical regions of Pakistan [4]. Most of the pomegranate orchards were found infested with root-knot nematodes [5, 6]. Sudheer et al. [7] reported that most of the nematode infested plants showed yellowing of foliage and stunted growth and these plants produced less or undersized fruits or did not bear any fruits. Khan and Shaukat [8] recorded twelve genera from the rhizosphere of pomegranate and the most dominant species was *Meloidogyne incognita* from Khuzdar and Kalat districts of Balochistan province. Grape (*Vitis vinifera* L.) which is an economically important crop has been facing many soil-borne pathogens and pests that damage or completely destroy the new roots of plants. Aballay et al. [9] and Baginsky et al. [10] established that several species of plant-parasitic nematodes (PPNs) have been reported to cause economic damage to grapevines and the most frequent species were *Xiphinema index, Meloidogyne ethiopica, Mesocriconema xenoplax*, and *Tylenchulus semipenetrans.* Peach (*Prunus persica* L.) is an important economic fruit plant of Balochistan, with an area under cultivation of 60.22 ha and production of 30.31 tons [11] also faces different diseases that cause reduction in its annual productivity. Di Vito et al. [12] noticed that the peach trees are subjected to various diseases throughout their lives and phytonematode infections in these trees are common. Several species of phytonematodes have been reported to damage the peach crops. Malo [13] reported that root-knot nematodes attack peach trees and weaken them to such an extent that they are easily affected and often killed by other pathogens or physiological conditions. Chitwood et al. [14] pointed out that *Xiphinema americanum* was predominant form in the vicinity of peach trees. Philis [15] found that *Meloidogyne* spp., attack young roots of peach which leads to stunting of trees and shortens lifespan. Apple (*Malus pumila* Mill.) and apricot (*Prunus armeniaca* L.) are also affected by many pests and diseases worldwide, but nematodes are considered important pests of apple and apricot as noticed by Aballay and Erikson [16], Islam et al. [17], Karanastasi et al. [18] and Khan et al. [19].

The current study focuses on the phytonematodes associated with fruit trees in Pakistan and that widely damaged by several species of phytonematodes. The investigation is designed to check the association, population density, incidence (%) and prevalence of nematodes associated with some important plants were studied in the fields of Pishin district, Balochistan.

2. MATERIALS AND METHODS

2.1 Collection and Isolation of Phytnematodes

Soil samples from three localities namely Killi Karbala, Huramzai and Barshore of Pishin district Balochistan, Pakistan during December, 2013 were collected for the estimation of infestation, population and prevalence of phytonematodes on different fruit trees including pomegranate (*Punica granatum* L.), grapes (*Vitis vinifera* L.), peach (*Prunus persica* (L.)), plums (*Prunus domestica* L.), tobacco (*Nicotiana tabacum* L.), apple (*Malus pumila* Mill.) and apricot (*Prunus armeniaca* L.). Samples were collected from the soil close to tree trunk at a depth of 20-30 cm depth. Approximately 2 kg of soil adhering the roots was procured. All Nematodes were isolated from 200 cm^3 soil by using method of Cobb's Decanting Sieving method followed by a modified Baermann's technique as described by Southey [20].

2.2 Soil Analysis

A total of 70 soil samples from three designated localities (Killi Karbala, Huramzai and Barshore) in the vicinity of fruit trees and crops were collected to analyze soil types, soil pH and water holding capacity of nematodes. Soil texture was determined manually [21]. The pH of soil was measured in soil paste (1:5 soil/dist. water) while water holding capacity was determined in accordance with the procedure of Shaukat et al. [22]. The soil was saturated in tin cans (with a hole in the bottom) and

weighed. The soil was then oven-dried (100 °C for 24 h) and the maximum water holding capacity was calculated as loss in weight (saturated soil – oven dried soil) and expressed as a percentage of oven-dry soil [22, 6].

2.3 Population Density, Prevalence and Incidence Percentage

Nematode densities in rhizosphere soil were determined by extracting nematodes from a 200 cm^3 by using the centrifugal-flotation method [23]. The frequency of occurrence (prevalence) and incidence of the disease in each locality was calculated by the following formula:

$$\text{Prevalence (\%)} = \frac{\text{Number of fields with nematode infections}}{\text{Total number of fields surveyed}} \times 100$$

$$\text{Incidence (\%)} = \frac{\text{Number of plants galled}}{\text{Total number of plants sampled}} \times 100$$

2.4 Identification of Nematdes

The nematodes and their different morphological stages and characters were identified with the help of Hartman and Sasser [24], Siddiqi [25], Ahmad [26] and Handoo [27]. Nematodes specimens were killed by hot-water bath and fixed in 3% formaldehyde. For identification of the ectoparasitic nematode species, nematode specimens were processed by Seinhorst's glycerol-ethanol method Seinhorst [28] and stained by NaOCl-Acid Fuchsin method Byrd et al. [29]. The root-knot nematode species were identified with the help of perineal pattern as described by Taylor and Netscher [30]. The nematodes were viewed through an electronic and stereomicroscope.

3. RESULTS AND DISCUSSION

Balochistan province has tremendous potential for developing fruit farms, comprising of agro-ecological zones endowed with a unique environment for production of a great variety of quality fruits. Abundance, prevalence and incidence of phytonematodes associated with fruit trees were examined. A total of nine genera of nematodes were recorded from three different localities and seven crops (Table 1). *Meloidogyne incognita* was the dominant species and recorded from four crops species, while *Helicotylenchus digonicus, H. pseudorobustus, Xiphinema americanum* and *X.*

Table 1. Summary of phytonemtaode species present in different investigated plant species of Pishin district of Balochistan.

Nematode species	*Pomegranate*	*Grapes*	*Peach*	*Plums*	*Tobacco*	*Apple*	*Apricot*
Helicotylenchus digonicus	+	-	-	-	-	-	-
H. indicus	-	-	-	-	+	-	+
H. pseudorobustus	-	-	+	-	-	+	-
Hoplolaimus indicus	-	-	-	-	+	-	-
Meloidogyne incognita	+	+	+	-	-	+	-
M. javanica	-	-	-	-	+	-	-
Paratylenchus holdemani	-	-	-	-	-	-	+
P. penetrans	-	-	-	+	-	-	-
P. scribneri	-	-	-	-	-	+	-
P. thornei	-	+	-	-	-	-	-
Rotylenchus dalhousiensis	-	-	-	-	-	-	+
Scutylenchus rugosus	+	-	-	-	-	-	-
Tylenchorhynchus annulatus	-	-	+	-	-	-	-
T. curvus	-	+	-	-	-	-	-
T. trilineatus	-	-	-	-	-	-	+
Tylenchus filiformis	-	-	-	-	+	-	-
Xiphinema americanum	-	-	+	+	-	-	-
X. basiri	+	-	-	-	-	-	-
X. index	-	+	-	-	-	-	-
X. rivesi	-	+	+	-	-	+	-

(+) = Presence and (-) = Absence

Table 2. Densities of plant parasitic nematode in 200 cm^3 soil in the rhizosphere of different plants species of Pishin district of Balochistan.

Plant species	*Helicotylenchus digonicus*	*H. indicus*	*H. pseudorobustus*	*Hoplolaimus indicus*	*Meloidogyne incognita*	*M. javanica*	*Paratylenchus holdemani*	*P. penetrans*	*P. scribneri*	*P. thornei*	*Rotylenchus dalhousiensis*	*Scutylenchus rugosus*	*Tylenchorhynchus annulatus*	*T. curvus*	*T. trilineatus*	*Tylenchus filiformis*	*Xiphinema americanum*	*X. basiri*	*X. index*	*X. rivesi*
Pomegranate	52	-	-	-	127	-	-	-	-	-	-	66	-	-	-	-	-	17	-	-
Peach	-	-	26	-	190	-	-	-	-	-	-	-	22	-	-	-	28	-	-	12
Plum	-	-	-	-	-	-	-	39	-	-	-	-	-	-	-	-	33	-	-	-
Tobacco	-	70	-	63	-	210	-	-	-	-	-	-	-	-	-	39	-	-	-	-
Apple	-	-	112	-	213	-	-	-	78	-	-	-	-	-	-	-	-	-	-	27
Apricot	-	59	-	-	-	-	37	-	-	-	86	-	-	-	41	-	-	-	-	-
Grapes	-	-	-	-	179	-	-	-	-	66	-	-	-	47	-	-	-	-	35	8

rivesi were isolated from only two crops. While, all other nematodes species were observed in rare cases.

The number of second stage juveniles of *M. incognita* ranged from 127 to 213 while that of *Xiphinema basiri* 17 per 200 cm^3 soil (Table 2). The highest number of nematode species such as *Meloidogyne incognita, Xiphinema americanum, Helicotylenchus pseudorobustus, Tylenchorhynchus annulatus* and *Xiphinema rivesi* was recorded from the rhizosphere soil of peach plants. The average population of *Meloidogyne incognita, M. javanica* and *Helicotylenchus pseudorobustus* were abundant, while *Xiphinema basiri, X. index* and *Tylenchorhynchus annulatus* populations were low. *Meloidogyne incognita* was recorded from maximum number of crop plants (four), followed by *Xiphinema rivesi* which was found associated with three crop plants.

Out of 70 soil samples from the vicinity of fruit trees and crops, 58 were infected with nematodes. The highest population and prevalence of nematodes was documented in the soil samples of Killi Karbala (26% and 66% respectively) followed by Barshore (21% and 60% respectively), while Huramzai exhibited lowest (15% and 47% respectively) as shown in Table 3.

Data presented in Table 4 indicates that *Meloidogyne incognita* was the most common nematode isolated from four plant species such as pomegranate, peach, apple and Grapes. However, *Xiphinema rivesi* was prevalent in peach, apple and grape. Maximum incidence percentage of *M. incognita* was recorded 76% from the soil samples of grape plants. However, minimum incidence percentage was 12% that was recorded from the soil of tobacco plants.

In present study, total of nine genera of nematodes were recorded from different localities of Balochistan which are highly damaging loss of fruit trees. These results are in agreement with those of Khan et al. [31] and also corroborate our study. They found eight different phytonematodes in different areas of Balochistan associated with the seedlings of peach, while most predominant nematode was *Helicotylenchus pseudorobustus* and the least frequent were *Meloidogyne javanica*

Table 3. Soil characteristics with population density and prevalence (%) of different localities in Pishin.

Locality	Soil texture	Soil pH	Max. water holding capacity (%)	Population density	Prevalence
Killi Karbala	Loamy sand	8.0	27.4	26%	66%
Huramzai	Loamy sand	8.2	26.7	15%	47%
Barshore	Sandy loam	7.6	35.6	21%	60%

Table 4. Phytonematodes incidence (%) in different plant species of Pishin district, Balochistan.

Plant species	Nematodes	Incidence (%)
Pomegranate	*Helicotylenchus digonicus*	22
	Meloidogyne incognita	42
	Scutylenchus rugosus	17
	Xiphinema basiri	32
Peach	*Helicotylenchus pseudorobustus*	57
	Meloidogyne incognita	65
	Tylenchorhynchus annulatus	33
	Xiphinema americanum	29
	X. rivesi	30
Plums	*Pratylenchus penetrans*	15
	Xiphinema americanum	31
Tobacco	*Helicotylenchus indicus*	39
	Hoplolaimus indicus	12
	Tylenchus filiformis	26
	Meloidogyne javanica	61
Apple	*Meloidogyne incognita*	56
	Helicotylenchus pseudorobustus	41
	Xiphinema rivesi	24
	Pratylenchus scribneri	19
Apricot	*Tylenchorhynchus trilineatus*	45
	Rotylenchus dalhousiensis	27
	Helicotylenchus indicus	30
	Pratylenchus holdemani	41
Grapes	*Xiphinema index*	57
	Meloidogyne incognita	76
	Tylenchorhynchus curvus	47
	Pratylenchus thornei	23
	X. rivesi	37

and *Tylenchorhynchus annulatuus*. In addition, the observations of Khan et al. [6] correspond with the findings of our study. They recorded several genera of nematodes from the rhizosphere of pomegranate and the most dominant nematode species was *Scutylenchus rugosus* followed by *Xiphinema basiri* and *Meloidogyne incognita.*

Similar findings were also reported by other researchers such as Aballay et al. [9] and Baginsky et al. [10] who showed that several species of nematodes including *Xiphinema index, Meloidogyne ethiopica, Mesocriconema xenoplax*, and *Tylenchulus semipenetrans* have been reported to cause economic damage to grapes and

completely destroying the younger roots of plants. Khan et al. [19] also concluded that *Meloidogyne incognita* and some other nematode infection cause noticeable damage to apple and apricot roots and consequently affect the fruit production.

4. CONCLUSIONS

Based on results of this study, it is concluded that soil factors are of considerable of importance to the fruit tree species and a number of nematode species are associated with the rhizosphere soil of fruit trees in Pishin district. The soils were infected by sizeable populations of phytonematode communities which can adversely affect growth and yield of some important fruit trees. Further studies on the host range, histopathology, actual damage, biological control, integrated control and strong management practices are warranted to gain better understanding of plant-nematodes associated with fruit trees of Balochistan.

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Research Article

Rice Noodles: Materials, Processing and Quality Evaluation

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Abstract: Asian peoples consume noodles as a staple food since ancient time. It is convenient, easy to cook, delicious and nutritionally rich product and is now gaining great appraisal outside Asia also. Generally, rice noodles are prepared from flour, salt, water and various optional ingredients. Rice flour is kneaded in the presence of water and salt to form dough and is then sheeted, compounded, steamed and cut to form a noodle strands. The noodle strands can be further processed (dried, fried, boiled and frozen) to develop various types of noodles based on consumer preferences. This review article focus on different ingredients and their functionality as well as the processes involved in transforming raw material to finished product. Protein, ash, dough strength and amylose concentration are very crucial regarding noodle quality. Variation in compositions affects the cooking, functional and eating properties of noodles. Due to the absence of gluten, rice noodles have less cohesive and extensive texture. Steaming gelatinizes rice starches up to some extent, which aids in the partial compensation of gluten role in rice based noodles. The trend towards gluten free noodle is due to their health beneficial effect as they help in lowering the risk of allergic reactions and celiac diseases, as well as induce lower glycemic index for patients suffering from diabetics. High quality noodle must be bright in color, have an adequate shelf life without oxidative rancidity or microbial spoilage, and have good textural and cooking properties.

Keywords: Rice noodle; raw materials; processing; quality characteristics

1. INTRODUCTION

1.1 History and Classification of Noodles

Since ancient times, noodles in various formulations and shapes have been used as staple food in many parts of Asia [1-2]. This is evident from the literature that Chinese were the first to introduce noodles to the world, rather than Arabs or Italians. Noodles were very popular during the era of Han dynasty (25-220 AD) in China. During the early 20th century, alkaline noodles were introduced in Yokahama city of Japan by Chinese immigrants. Later on, Japanese develop instant noodles by a different process, which became the most popular food not only in Asia but all over the world [1]. Both China and Japan did a lot of innovation and employed modern technology in noodle processing that substantially increased the consumption and acceptance of noodles outside Asia also. Noodles experienced substantial evolution and migration in spite of its origin due to the increase in globalization [1, 3].

Noodles are classified into different types on the basis of raw material, processing methods, salt composition, size of noodle strand and form of noodles in the marketplace. Wheat noodles, rice noodles, starch noodles, mung-bean starch noodles and buckwheat noodles are few examples of noodle types which are available in the market nowadays. Noodles are classified into hand-made standard or flat noodles (teuchiudon or teuchihira-men) and thin hand-made noodles (tenobe so-men) based on manufacturing involved. Additionally,

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these are also classified on the basis of form of product in the marketplace i.e. instant noodles, boiled noodles (yude-men), dried noodles, (kan-men), steamed noodles (mushi-men), frozen boiled noodles, instant cup noodles, and machine made noodles [1]. Noodles are also classified as Japanese type wheat noodles, buck wheat noodles (Soba), Chinese type wheat noodles, Naengmyon noodles (Korean type noodles), starch noodles, rice noodles and pasta based on the raw materials and other ingredients used [3, 4]. Rice noodles are prepared by gelatinization of dough using cold extrusion process [5].

1.2 Rice Noodles

Noodles are safe and nutritious product that conforms to the set food standards of various countries. With the increase in Asia pacific economy, the demand for quality noodle products among consumer gets higher [1]. Rice noodles are the most consumed form of rice product next to cooked rice grain in Asia [6]. Noodles may either be served by frying and mixing with vegetables and meats or served as a soup noodle by boiling in a broth. Rice protein lack gluten; hence lack the functionality of continuous visco-elastic dough. Rice flour is therefore pre-gelatinized in order to act as binder for the remaining flour. The extent of pre-gelatinization plays a vital role in providing desirable texture to the noodle strands. The level of gelatinization is maintained adequately to develop the desired binding power during the process of extrusion; though too much gelatinization may create handling problems [6]. Rice noodles are commonly prepared by two main methods; sheeting of dough to develop flat noodles and extruding to develop vermicelli. The raw materials for rice based noodles are usually evaluated by determining their functionalities; processes involved and desired end product [1].

Generally, rice noodles are made from flour containing high amylose concentration (> 22%), which contributes to the gel network. It provides firm structure and desirable properties to noodle [5-6]. There is significant association found between amylose and acceptability of rice noodles [7]. The wide variation in physical and chemical properties of rice flour greatly influences the textural quality of rice noodles. Additionally, rice noodles properties are also influenced by paste viscosities, swelling power (SP) and gel texture of rice starch. The high amylose concentration in rice flour gives noodle with bright color and low bulk density because of their educed swelling power [8-10].The chemical composition i.e. protein, fat, carbohydrate and ash concentration of rice noodles were found to be 7.20%, 0.84%,91.7% and 0.24%, respectively [11]. The texture of rice noodles is less cohesive and extensive due to the absence of gluten. The textural, cooking and sensory properties depend upon the pasting and physicochemical attributes of rice flour obtained from different rice varieties [5, 9, 12]. Flour particle size can also influences the properties of noodles [9, 13]. However, noodles made from flour having smaller particle size showed better textural properties [13]. Similarly, the smaller particle size had highest water absorption index, hot paste viscosity, peak viscosity, and breakdown, final or cold paste viscosity and gel hardness, but the lowest gelatinization temperature [5, 13]. However, fat concentration did not significantly influence the properties of noodles [5, 10, 13].

Rice vermicelli is prepared from flour having high amylose concentration, which is obtained by steeping followed by wet milling. The flour is filtered, pulverized and molded into balls that are pre-cooked in boiling water for 20 minutes or steamed to facilitate surface gelatinization. The partially cooked balls are kneaded, which causes uniform distribution of the gelatinized starch all over the dough which performs a binding role. The dough is then passed through the extruder or noodle making machine to make noodle strands. The noodle strands are then put in boiling water and taken out when cooked adequately. Immediately, the cooked noodles are cooled by transferring into a cold water container. The noodles are then allowed to dry by placing them in racks. On the other hands, the noodles can also be subjected to steaming process for a time period of 10-15 minutes, by directly placing them in racks, followed by tap water washing, and drying. Dry milling is preferred to wet milling for making rice noodles in Japan. The dry milled flour is mixed with water and heated for about one minute at 100 ^{o}C to cause

partial gelatinization of starch and then kneaded by the help of screw kneader or by hands [1, 13].

Flat or sheeted fresh rice noodles are famous in many areas of Southeast Asia, southern China and Japan. The dough is placed in a rotating heated drum to form sheets. The sheets are then placed in a steamer that causes partial gelatinization of starch. About 1 mm thick sheets are passed through the cutting rolls to form noodle strands. The noodles are then served either as fresh rice noodles or can be dried before sale. The process involved in the preparation of Japanese rice noodles comprises of the following steps; washing milled rice, pulverizing, steaming, kneading and sheeting. The final thickness of the noodle sheet is maintained at about 1-2 mm before cutting [1, 9, 14].

2. RAW MATERIALS FOR RICE NOODLES

The basic ingredients used to develop rice based noodles include flour and water, along with additional ingredients i.e. salt, oil to improve the quality of final product. Raw materials are judged by determining their physicochemical properties and processing parameters. It is important that raw materials possess appropriate functional and processing properties in order to develop a quality product [1, 15].

2.1 Rice Flour

Rice flour is obtained from fine milling of rice kernels. Rice flour may be made from either brown rice or white rice [16]. It is energetic and basic food consumed on a regular basis and has a very high digestibility value. Rice flour comprised of about 0.4–0.8% fat, 7% protein and 78% carbohydrates[17]and provide substantial amount of B vitamins; thiamin, niacin and riboflavin [18]. Different type of products are made from rice flour, such as bread, noodles, cakes, and other conventional products developed in the homes or in the industries, across the world [1, 10]. Different types of noodles consumed in the Asia-Pacific region. Each noodle is preferred and consumed in different culture within different region of Asia. Hence, it is not easy to discuss flour specifications or quality, without recognizing the type of noodle, method of production, production environment, existing facility and regional preferences [1].

The flour physicochemical properties would facilitate the understanding of its possible uses and applications [11]. Brown rice variety had the highest protein concentration (8.16%) and lowest fat concentration (0.07%). However, white rice variety has high amylose concentration (27.71%), while brown rice variety has low amylose concentration (3.36%). On the other hand, white rice had 25.0% amylose, 8.0% protein and 2.2% fat concentration [19].Rice flour is categorized according to the presence of amylose concentration, as either high amylose (25-33%), intermediate amylose (20-25%), low amylose (12-20%), very low amylose (2-12%) and waxy (1-2%). On the basis of cooking properties, rice is categorized into two groups; waxy and non-waxy rice. Waxy rice is mostly composed of amylopectin and produces chewy and sticky structure; whereas non-waxy rice contains 10-20% amylose and produce firm noodle [20].

The quality attributes of rice grains are appearance, cooking and eating properties as well as nutritional value [21]. Rice varieties containing high amylose concentration, high gel consistency and low gelatinization temperature are appropriate for making rice noodles [7]. Rice flour having intermediate amylose concentration produce soft texture noodles. Such noodles lead to high solid loss in cooking water. Noodle made from very low amylose concentration flour lead to very poorly textured noodles and is therefore not used in preparing noodles [22-23]. The granule size of rice starches may vary from 3 to 8 μm and is much smaller from granules obtained from other starch sources. The use of larger granule size (> 20 μm) for noodles making showed higher processing ability and quality attributes [24]. Rice flour starches exhibited weaker resistance toward shear forces and do not form strong gel. It also loses thickening power and viscosity significantly during cooking process. The gelling property of rice starch is dependent upon rice varieties, amylopectin and amylose concentration, as well as the duration of the ageing [25]. Physical modification of flour such as addition of water and heat treatment improves the eating and cooking properties of rice noodles [7].

The adaptation of proper milling process is very important to obtain flour of desired properties i.e. bright color, fine particles, low ash concentration and damaged starches. Every type of noodles has their own specific protein range. The milling procedure must be adopted in such a way as to ensure proper separation of endosperm and bran, including tempering as well as break release adjustment in the mill [26]. Usually, flour containing high protein concentration is required to develop dried noodles, while boiled or fresh noodles are made from flour containing lower protein concentration. However, high level of protein in dried noodles helps to keep the noodle texture during drying. Protein concentration plays vital role in the preparation of instant noodles, because fat uptake decreases as the protein concentration increase during the frying process [27-28]. The natural color pigments in flour are destroyed by bleaching. Noodle darkening increases with higher extraction rate of flour. The high bran level resulted in dark color noodles due to the greater level of polyphenol oxidases in the bran layer. Low ash concentrations and low extraction rate are mostly preferred to develop high quality noodles with bright and clean appearance [1].

On the other hand, thermal properties such as gelatinization, pasting and retrogradation impart significant role in product development. It controls the rheological properties and determines the quality of starch based products [29]. Gelatinization refers to the disruption of molecular order within the starch granule, thereby leading to irreversible changes in properties i.e. loss of birefringence, granular swelling, loss of crystallinity and starch solubilization. The gelatinization process is governed by the concentration of starches, types of granule and amylose and amylopectin concentration. While retrogradation is the reassociation of starch chain into an ordered structure after starch solutions are cooled [30]. Zhou et al.[31]found no significant difference in onset temperature (T_o), while significant difference was noted in peak temperature (T_p), gelatinization enthalpy (ΔH) and conclusion temperature (T_c) in flour obtained from three different rice varieties, which were stored at 4°C and 37 °C for 6 months. Hormdok and Noomhorm [9] found that rice starch had 67.7, 73.49, 78.75 ^oC and 13.21 j/g in case of T_o, T_p, T_c and (ΔH), respectively. Bao et al [32] also observed similar results regarding rice starch. They concluded that gelatinization temperature is a critical step, as it is an indicator of processing and cooking quality. Gelatinization leads to collapse of double helical structure and crystallinity, which resulted in crystals melting at different temperature to form suspensions of starch mixtures. The variation in morphology and rigidity of starch granule causes differences in gelatinization peaks of waxy and indica starch. Amylose and amylopectin concentration also affect the gelatinization peak [30]. Tan et al [33] reviewed that long chain amylopectin might also be a factor to higher gelatinization temperature of starches. Therefore, it can be concluded that starch thermal properties are influenced by various factors like, variety, starch source, morphology of granules, amylose, amylopectin concentration etc. Flours containing high percent crystallinity and amylose concentration exhibited higher gelatinization parameters due to the rigid amorphous regions of starch granule by the association of amylose chains. This might increase the stability of amorphous region, thereby leading to higher energy input for gelatinization process [34].

Starch gel is defined as a continuous network of solid-liquid phases in which liquid is dispersed in the solid phase [35]. Hydrogen bond is formed between amylose molecules as well as with amylopectin branches of swollen granules. Morphology of starch gels and its strength is effected by different factors i.e. starch sources, cultivar or variety of each source, granule size and shape, moisture concentration, ratio of amylose to amylopectin, gelatinization time and temperature and pH [9, 36-38]. Comparatively, the gelling strength of aged rice flour is superior to flour obtained from freshly harvested rice grains [39]. Hormdok and Noomhorm [9] also observed that ageing of rice flour had increased the gel strength significantly, as evident from the observed values of 27.38 (flour from freshly harvested grains) and 33.13 g (aged rice flour). Huang et al.[40] made mixed gel from two rice varieties (Japonica and Indica starch), hydrocolloids (carrageenan and gellan), deionized water and $CaCl_2$. They observed the influence of rice starch, hydrocolloids and its concentration on the quality of gel via texture profile analysis. It

was found that the texture of the gel depends on rice variety, hydrocolloids and its concentration. Addition of 0.2% (w/w) carraggnan to the Indica rice starch improved the texture of rice gel. While, addition of 0.3% (w/w) gellan to the Indica rice starch enhanced the adhesiveness/ hardness ratio.

Likewise, pasting is an important functional property, which occurs after gelatinization in starch dissolution. It is an important index for evaluating the starch properties of rice [39]. It consists of swelling of starch granules, leaching of molecular components from granules and finally total rupture of granules. Several parameters can be acquired from the pasting curve, which manifest the extent of disintegration and beginning of retrogradation [41]. However, starches obtained from tubers and roots showed weak intra-granular bonding, lower gelatinization temperature, rapid and uniform granular swelling, paste clarity and high viscosity compared to cereal starches [41]. The peak viscosity (PV), trough (T), break down (BD), final viscosity (FV), set back (SB) and pasting temperature of rice flour were 253.17, 191.29, 61.88, 351.38, 160.08 RVU and 76.38 °C, respectively [9].The pasting properties of rice flour from aged (paddy and milled) rice and fresh rice from two rice varieties stored at different temperature conditions for a storage period of 10 months is shown in table 1. The SB and FV values were increased with the increase of storage temperature and time. Moreover, the rise in SB values showed a higher degree of retrogradation due to the increase in rice firmness [42]. The rice flour obtained from milled rice and stored paddy was firmer compared to flour procured from fresh rice; hence stored rice gave less sticky texture [39]. Ageing of rice and amylose concentration significantly influenced the pasting properties of rice [43]. Kanlayakritand Maweang [44] studied the pasting properties of rice flour obtained from stored paddy and freshly milled rice under different

Table 1. Comparison of pasting properties of rice flour from fresh rice and aged (paddy and milled) rice from two rice varieties stored at cold room, room temperature and warehouse for 10 months [44].

Rice sample	Storage condition	Peak Viscosity (RVU)*	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)
Kalasin11	Fresh rice	247.64 ± 3.95^{f}	131.66± 1.80^{f}	115.98 ± 5.75^{e}	267.63± 3.95^{g}	135.97 ± 5.75^{d}
	Room Temperature[1]	199.60 ± 3.93^{j}	151.62± 2.26^{bc}	47.99 ± 1.68^{i}	334.33± 1.97^{b}	182.72 ± 0.29^{b}
Paddy	Cold Room[2]	225.66 ± 2.64^{h}	143.45± 1.17^{de}	82.21 ± 3.81^{g}	282.81± 3.13^{e}	139.36 ± 1.96^{d}
	Warehouse[3]	186.99 ± 6.26^{k}	154.54± 3.81^{ab}	32.46 ± 10.08^{j}	356.49± 3.15^{a}	201.96 ± 0.66^{a}
	Room Temperature[1]	211.79 ± 3.50^{i}	147.27± 4.26^{cd}	64.52 ± 7.76^{h}	322.48± 3.17^{c}	175.22 ± 1.10^{c}
Milled	Cold Room[2]	239.51 ± 2.50^{g}	138.63± 2.53^{e}	100.88 ± 0.03^{f}	276.50± 0.93^{f}	137.87 ± 1.61^{d}
	Warehouse[3]	201.94 ± 3.52^{j}	152.58± 2.60^{bc}	49.36 ± 6.12^{i}	331.47± 1.66^{b}	178.89 ± 4.26^{bc}
KDML105	Fresh Rice	331.62 ± 4.58^{a}	126.34± 4.06^{f}	205.28 ± 0.52^{a}	219.68± 1.21^{j}	3.34 ± 2.85^{g}
	Room Temperature[1]	288.50 ± 3.92^{d}	155.86± 4.77^{ab}	132.64 ± 0.84	265.44± 1.02^{g}	109.58 ± 3.75^{f}
Paddy	Cold Room[2]	303.34 ± 2.95^{c}	141.66± 2.02^{de}	161.68 ± 4.97^{c}	234.38± 2.09^{i}	92.72 ± 4.11^{g}
	Warehouse[3]	276.57 ± 3.08^{e}	159.57± 1.48^{a}	117.00 ± 4.55^{e}	293.51± 2.41^{d}	133.94 ± 3.89^{d}
	Room Temperature[1]	301.40 ± 2.64^{c}	142.04± 1.29^{de}	159.37 ± 3.94^{c}	251.76± 1.61^{h}	109.72 ± 0.31^{f}
Milled	Cold Room[2]	322.90 ± 3.00^{b}	139.58± 0.90^{e}	183.33 ± 3.90^{b}	231.39± 1.06^{i}	91.82 ± 0.16^{g}
	Warehouse[3]	287.55 ± 1.94^{d}	151.08± 1.08^{bc}	136.47 ± 3.03^{d}	274.38± 2.09^{f}	123.30 ± 3.17^{e}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05).
[1]Room temperature (30±5°C),
[2]Cold Rooms (20±5°C),
[3] Warehouses (40±5°C).
*RVU = Rapid Visco-analyzer Unit

storage conditions. Amylose concentration significantly influenced the RVA pasting properties of fresh rice flour. On the other hand, stored paddy showed significant difference in pasting properties during the storage period. Peak viscosity (PV), trough (T), final viscosity (FV) and setback (SB) of KDML105 rice flour were lower than Kalasin11 rice flour that were obtained from milled rice and stored paddy, respectively. Furthermore, it was observed that the changes in pasting properties of milled rice were lower than stored paddy. It was noticed that the paste viscosity decreased as the ageing process proceed [44]. The structure of rice granules became more organized during storage. Although, the surface of granules characterizes the major barrier to hydration, consequently, pasting may be affected by the presence, nature and orientation of surface proteins and lipids. Protein is basically composed of amino acids and is hydrophilic in nature. Any changes in the granules during storage and processing could alter their hydrophilicity, which would influence the hydration and swelling of granules, thereby influencing the pasting properties of rice flour [31, 42-43, 45]. Storage of rice at cold temperature stopped alterations in the pasting properties [31, 46].

Techawipharat et al. [47] observed that waxy rice starch had much lower pasting properties than normal rice starch. This is due to the lower amylose concentration (< %) in waxy rice starch. Granular interaction and amylose concentration significantly affected the starch pasting properties. Similarly, storage temperature and duration also influenced the pasting properties of rice flour [31, 43, 45-46]. Inglett et al.[48] investigated the pasting properties of blends of rice and wheat flours. It was observed that the pasting properties of wheat flour increased with the increase in the concentration of rice flour in the blends. Nura et al. [13] evaluated the pasting properties of rice flours with different particle sizes. It was found that variation in particle size influenced the pasting properties as shown in table 2. Pasting temperature of rice flour samples was decreased significantly with the reduction in particle size. This could be attributed to the smaller particle size, which provides greater surface area for rapid hydration. The starch granules swell quickly leading to gelatinization of starch at lower temperature. Rice flour with smaller particle size attained the onset gelatinization temperature earlier. Peak viscosity (PV) shows the highest viscosity attained by starch under given conditions during the gelatinization process (Shuey and Tipples, 1994). Rise in PV indicates the ability of starch granules to swell up to the extent before physical breakdown occurs [49]. However, set back (SB) was comparatively higher in all the flour samples evaluated. This might be due to leaching of amylose in starch gel that caused quick retrogradation and gave harder texture after cooling [13]. The SB shows the retrogradation tendency and is determined by the difference between PV and HPV [5]. On the other hand, hot paste viscosity (HPV) is affected by the formation of amylose-lipid complex, granule swelling, amylose exudation, and competition between remaining granules and exuded amylose for free water [50].

Table 2. Pasting properties of rice flours with different particle sizes [13].

Particle Size (µm)	Peak Viscosity (RVU)*	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Pasting Temperature (°C)
140	221.21±1.04^{d}	150.67±0.50^{b}	70.54±1.54^{a}	317.38±4.88^{c}	96.17±5.92^{a}	82.37±0.30^{c}
125	226.58±2.76^{c}	154.78±4.09^{ab}	71.81±2.68^{a}	321.86b±4.44^{c}	95.28±2.51^{a}	81.52±0.06^{b}
100	229.08±1.59^{bc}	156.53±2.87^{ab}	72.56±4.44^{a}	326.14±1.98^{ab}	97.06±3.54^{a}	81.40±0.00^{b}
80	232.17±1.26^{b}	159.17±8.03^{a}	73.00±9.27^{b}	327.97±4.71^{ab}	95.81±5.97^{a}	80.97±0.51^{a}
≤63	237.36±1.28^{a}	160.56±2.65^{a}	76.81±3.62^{a}	332.53±5.76^{a}	95.17±6.57^{a}	80.81±0.15^{a}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)
*RVU =Rapid Visco-analyzer Unit
Values are Means ± SD of triplicate determinations

2.2 Water

Water is considered to be the second key raw material used in noodle making after flour. The proportion of water used in noodle making should be optimum (30–35%) in order to optimally hydrate the flour for making dough of proper consistency [2]. Addition of excess water results in soggy dough, while too little water creates difficulty in dough formation and sheeting [51]. It furnishes the required medium for all the biochemical and physicochemical reactions in transforming the raw components into finished products. It can dissolve the water soluble components prior to mixing. The water used for making noodle should meet the sanitary requirements to produce high quality products [1, 2, 52].

Water varies in characteristics depending on its origin. Surface water usually contains higher level of chemical, microbial and organic contaminants compared to ground water. However ground water is relatively richer in dissolved inorganic substances. Water are characterized as either hard, soft, saline or alkaline depending upon the amount and types of mineral salts available in natural water, which has a pH value between 5.8 and 8.6 [1]. All these types of water affect flour hydration, starch gelatinization, sheeting process and texture of noodles. Hard water is not used generally because it reduces the water retention capacity of the flour. The available ions in hard water substantially affect the gelatinization of starches in subsequent steaming or boiling process. While, very soft water yields sticky and soft dough sheets. Low to medium hard water is considered desirable for noodle processing. The high alkaline water is due to the presence of magnesium and calcium ions. After boiling, the pH of alkaline water rises to 9 due to the decomposition of bicarbonates upon heating to form the subsequent carbonates. Therefore, alkaline water is not used in the processing of noodles, particularly for manufacturing boiled noodles. Organic acids i.e. acetic, citric, lactic, malic or citric acids are added sometimes to adjust the pH of water for the preparation of boiled noodles [1-2, 9, 52].

2.3 Salt

Salt is another basic ingredient which is used in noodle preparation, which is added up to 1-3% of flour weight. However, about 8% of salt could be used in the formulation for processing of boiled Udon and hand-made noodles. Salt play three major role in noodle processing. The most important function is its tightening and strengthening role in dough gluten that is attributed to its inhibitory effect on proteolytic enzymes. While, other evidences shows a direct relationship between protein and salt. It substantially enhances dough sheeting properties, particularly at a higher water absorption index. The next important role that salt contribute is the improvement of texture and flavor. In addition of providing salty taste, it also acts as a flavor enhancer in many other foods. It imparts fullness to the "mouth-feel" and masking possible off-taste. Salt significantly reduce the cooking duration and provide elastic and softer texture. The third important role of salt is its inhibitory effect on microbes and various enzymes. Salt retard the spoilage and oxidative reactions at high humidity and temperature, thereby prolonging the shelf life of products. Higher concentration of salt in noodle formulation also reduces the drying rate [1].

However, by considering the consumer preference, alkaline salt are used alone or in combination with various salts. Potassium and sodium carbonates are the most commonly used alkaline salts. While, other alkaline reagents i.e. bicarbonates and sodium hydroxide are also added occasionally. Alkaline salts are added at a rate of 0.5 to 1.5% in noodles having strong alkaline flavor, while added at a rate of 0.1 to 0.3% in few noodle types for the purpose of improving their quality [1]. The yellowish color of alkaline noodles is provided by the natural pigments such as flavonoid present in flour, which behave as color in acidic medium, while turn to yellow in alkaline medium. A greenish-yellow color is given to the noodles by the incorporation of potassium carbonate that also have less reflectance as compared to noodles prepared by the addition of sodium carbonate. However, sodium hydroxide gives more yellow and brighter noodles. Addition of alkali gives inelastic dough that can hardly be compressed during sheeting. It provides a firm texture compared to noodles made from only salt [1, 28].

2.4 Oil

After the process of steaming and molding, instant noodles are mostly fried in oil. Oil used in noodle processing must be about 20 percent of the noodle weight. Among the different types of oil available in the market, palm oil is extensively used in Asia, due to its availability, heat stability, better frying performance and cost effectiveness [1]. Similarly, partially hydrogenated canola and soybean oil is used to fry instant noodles. The degree and conditions of the hydrogenation must be balanced to provide desired properties. The oil should be selected based on the consumer preferences, as the oil compositions can significantly influence the flavor of final product. Usually, the oil deteriorates during cooking due to complex series of chemical reactions [14]. Thermal oxidation causes decompositions of non-volatile and volatile components. These decomposed products build up to a greater extent with extended heating and results in deterioration and sensory failures of the finished products. Hence, stability of oil during heating process is a great concern in the selection of oil. Furthermore, non-refined oils should not be used for frying purpose, as it can cause undesirable changes in flavor and color of the noodles. The specification mostly considered in selecting frying oils include flavor, color, peroxide numbers, free fatty acids, smoke point, melting point and iodine number [1, 14].

2.5 Improvers

Hydrocolloids and polyphosphates are commonly used to improve the overall quality of noodles. The use of polyphosphate increases the gelatinization of starch and water retention ability of the noodles during cooking. It also modifies the properties of dough and retards formation of off-color in raw noodles by acting as chelating agents. It is mostly added at 0.1% in the flour [1]. Similarly, hydrocolloids i.e. guar gums are extensively used in the processing of rice noodles. They are hydrophilic in nature and increase the water binding capacity of the flour. Gums added at a level of 0.2 to 0.5% of the flour weight enhanced the water absorption capacity and altered the texture properties and overall mouth-feel of the end product. Usually, gums are added in the salt solution prior to mixing of dough. Synthetic and natural colors can be added to different types of noodles (alkaline noodles, tea noodles and vegetable noodles) in order to improve their natural color [1, 22].

2.6 Preservatives

The shelf life of raw noodle could be prolonged by inhibiting growth of micro-organisms with the inclusion of alcohol in the formulation [42, 44]. Usually, the noodles are immersed in dilute solution of organic acids prior to packaging. Steamed and deep-fried instant noodles have comparatively higher fat concentration (> 15%), hence there is greater chances of oxidative rancidity. The use of antioxidants such as butylated hydroxy-anisole (BHA), tertiary-butylhydroquinone (TBHQ), butylated hydroxytoluene (BHT) and propyl gallate are commonly used to avoid oxidative rancidity. Among these, TBHQ greatly reduced the oxidation process [1, 31].

3. PROCESSING OF NOODLE

Regardless of the great variance in size, shape and formulation; the noodle making process is constant for all types. Generally, it consists of dough mixing, dough sheeting, compounding of dough sheets, and reduction in sheet thickness and formation of noodle strands. The noodles can be processed further in various ways after cutting. Afterward, the noodle strands can be distributed directly to the market or can be marketed as a raw noodles or can be dried, boiled, fried, frozen, steamed or combination of these processes can be used to develop large array noodle types[1].On the other hand, Hormdok and Noomhorm [9]made noodles by a different method. Instead of dough, slurry was prepared by mixing rice flour with water to a concentration of 40g/ 100g. The slurry was allowed to equilibrate for 60 minutes and poured to a stainless plate of 1 mm thickness to form a sheet. It was then steamed for 4 minutes and then allowed to cool at ambient temperature. The sheets were then cut into a strips of 3 mm and dried to 10-12% moisture level at a temperature of 40 °C. Rice noodles are mostly prepared by these two aforementioned methods.

3.1 Mixing

Mixing is the initial process in the formation of noodles. Water is added to flour in a container and other ingredients are also mixed. The ration of flour to water must be appropriate in order to make dough of optimum consistency. Mixing resulted in a uniform distribution of ingredients and also even hydration of flour. In the noodle making industry, two types of mixers are mostly used: the vertical mixer and the horizontal mixer. Generally, the mixers work at a speed of 70 to 100 rpm for 10-20 minutes and provide proper mixing and some kneading actions. However, vertical mixer is usually used on a large scale continuous product of noodles. The blades of vertical mixers have a large surface area that aid in the distribution of water evenly throughout the flour during the initial stage of mixing. It also provides a certain extent of kneading action after sufficient hydration of the flour. On the other hand, the horizontal mixer has single shaft or double shafts. The double shaft horizontal type mixer has shown best result in the mixing of dough. The blades of the shaft move in opposite direction, so that the dough crumbs move both horizontally and vertically during mixing [1].

Different types of mixers are also developed in the industry for performing noodle mixing i.e. low speed super mixer, continuous high speed mixer and the vacuum mixer. Low speed super mixer is used to mix dough with higher water absorption capacity. It is considered a copy of hand mixer and performs mixing at a speed of less than 10 rpm to minimize damage to the starch and protein matrix [1]. While the continuous high speed mixer is used to mix water and flour evenly in a very quick time. Water is added to the flour, which is rotated at a speed of 1500 rpm. High speed mixing leads to the formation of greater surface area for maximum hydration of water. Nowadays, vacuum mixer is used extensively in noodle industry. The vacuum mixing let addition of extra water to the flour without effecting processing efficiency [1, 5, 50].

The process of mixing is affected by flour quality, the addition of certain components, the volume of water added, the humidity and temperature of the processing environment. The water hydration correlates positively with protein concentration and can form dough crumbs of large size, consequently need less time for mixing [5, 34]. The greater level of damaged starch granules resulted from the milling of flour can also contribute to the increased water absorption capacity [50]. The concentration of water should be optimized in order to develop dough with good processing characteristics [5]. The ingredients such as salt and alkaline salt can also help flour hydration during mixing. Mixing process conducted at lower temperature slow down the hydration of flour. It is also not desirable to perform mixing process at a temperature of greater than 35^{o}C, as enzymatic activity and protein degradation can occur at such higher temperature. The optimum temperature is for making proper noodle dough is 25-30 ^{o}C [50]. Afterward, the dough is rested for some time that allows uniform hydration of flour particles and allows distribution of water to the dough mixture. The crumbly dough is agitated at a speed of 5-8 rpm for 10 to 20 minutes during the resting stage that avoid development of large dough crumbs and also facilitate dough feeding during the sheeting process [1, 5, 34, 50].

3.2 Steaming

The process of steaming is carried out in manufacturing rice noodle. During streaming, starch gelatinization and protein denaturation takes place in wet raw noodles. The cooking of noodles depends upon the original water, temperature and pressure of the steam and the time the product is exposed to steaming process [5]. Noodles steamed with hot water spraying speed up the starch gelatinization process and are stopped by washing with cold water. The dough must have high water absorption capacity and the steam must be highly saturated in order to develop quality steamed noodle. The steaming process is critical for noodle cooking. Under-steamed noodles are hard inside and causes problem in subsequent processing such as stir-frying prior to serving. While, over-steamed noodles are sticky and soft. For stir-frying the appropriate level of moisture must be about 59–61% in steamed noodles [1, 5].

Fari et al. [5] prepared noodle from 1 kg rice flour, which was mixed in a Hobart mixer to form dough. The dough was steamed for 30 minutes in a kitchen steamer. Then the dough was kneaded in

order to distribute the partially gelatinized starch. Afterward, the dough was extruded in a pasta machine, fitted with a die having a pore size of 0.1cm. The noodle strands were steamed for 15 minutes and placed in an electric dryer at 40 ˚C for 4 hours. Detchewaet al. [53] also steamed the rice dough in a steam cooker for 30 minutes. After streaming, the rice dough was kneaded and extruded via a spaghetti die in a laboratory scale extruder. The rice spaghetti was dried till the attainment of 10% moisture concentration in tray drier. The steaming process is an important step in the production of instant noodles and rice noodles. Higher gelatinized starch is needed for the manufacturing of air-dried instant noodles. The steaming process takes less time in case of deep-fried noodles compared to hot air-dried noodles. Excessive starch swelling must be avoided during the steaming process, as it can cause many processing problems [1, 14, 55].

3.3 Sheeting

Since adequate hydration of flour particles are done after mixing and resting of dough. Starch gelatinization in rice based noodles takes place during the sheeting process. The uniform development of protein matrix with sufficient extensibility and elasticity is vital to obtain better processing and eating properties of the final product [1, 56]. The neighboring endosperms mix together to form continuous protein matrix during compression. Sheeting of noodle dough is proposed to obtain smooth sheets of dough with proper thickness as well as uniform and continuous gluten matrix and gelatinized starches distributed throughout the dough sheet [50]. The crumbly dough is conveyed to a hopper or sheeting rolls, and passed through the sheeting rolls to develop continuous dough sheets. After compression, the dough sheets are usually of non-uniform texture with rough surface. Two sheets of dough are then folded before the next pass. The combined sheets are then usually rested for few minutes to several hours. The maturing of dough at this stage helps the following sheet reduction process and gives a uniform protein network [1, 5, 50, 53, 56].

After the resting step, the thickness of the compounded sheets is reduced by passing through the sheeting rolls that have a gradually reduced gap in between. The number of sheeting rolls varies from three to five [1]. The final sheet thickness is maintained according to the type of noodles developed [54]. In modern noodle making industries, sheeting in conjunction with increased hydration has improved the eating quality of noodle. A homogenous protein matrix can be attained during sheeting that aid to develop noodle with best eating quality. The major factors involved in the sheeting process are reduction rate, speed, number of passes, temperature, size, and position of the sheeting rolls. The thickness of dough sheets must be reduced gradually in order to minimize surface damage. This can be achieved by controlling the gap setting in a series of smooth rolls [1]. After compounding, the thickness of dough sheets should be reduced to below 40 percent. The final sheet reduction should be no more than 10% before cutting. The roll diameter should decrease gradually with each successive pass, so that pressure and compression distance are lowered also. With the increase in roll diameter, the horizontal movement of sheeting rolls increases. After each passage through the roller, the length of dough sheet increases. However, over-stretching of dough sheet could occur by performing the process at very high speed. The temperature of the sheeting rolls is maintained at proper temperature to give a desirable dough sheet [1, 5, 54, 56].

3.4 Cutting

The noodles are cut into strands after the desired thickness is achieved during sheeting. The shape and width of the strands are identified by means of the cutting rolls [1, 5]. The cutting machine comprised of a pair of slotted rolls having similar slot widths. The rolls for cutting are arranged in a linear fashion, with the front one turning counter-clock wise and the rear one turning clockwise with identical speed. The cutting force is produced among the adjoining two pointed slots edges of the cutting rolls. A comb is there at the bottom of every cutting roll to avoid sticking of noodle strands to the rolls. The final shape of noodle strands is based on the slot groove, the thickness of the dough sheet and the width of the slot. The shape mostly preferred is square, rectangular and round [1]. For the specification of noodle cutter there are

two systems, namely imperial and metric. In the imperial system, noodle strands is cut to a width of 25.4 mm, while in the metric system, the noodle strands of 30 mm width is cut down according to the assigned number of the cutting rolls. Finally the strands are cut into appropriate lengths through the help of length cutter. However, the noodle strands are fed continually into a moving net conveyor in case of instant noodle production that moves slowly as compared to the cutting rolls. The difference in the speed of feeding of noodles and net traveling resulted in a distinctive wave to the strands of noodles. After steam cooking, noodle strands are cut into desirable serving size [1, 5, 14].

3.5 Drying

The noodle shelf life can be extended considerably by limiting the biochemical and microbiological stability, which can be achieved by drying the noodle strands to a minimal moisture level. The process of drying is achieved by air drying, vacuum drying or deep frying [1]. Deep-frying is done in order to develop deep-fried and steamed noodles. The application of vacuum drying in the noodle industry is a newer method for drying noodle strands. Vacuum-drying of frozen noodles are usually performed in order to manufacture better quality end product. Drying by air is classified in to two basic types; hot air drying (>70 ^{o}C) and non-hot air drying (<50 ^{o}C) depending on the temperature used for drying purpose. The process of hot-air drying is applied to develop dried instant noodles and steamed noodles, while non-hot air drying is provided to develop regular dry noodles. The uncooked raw strands of noodles are hanged on rods in the drying chamber, where ventilation, relative humidity and temperature are synchronized. The rods travel through various sections of the drying tunnel. Water is evaporated from the surface of noodle by air drying. The driving force needed for removal of water is the differences in the vapor pressure of noodle surface and the partial pressure of the vapor in the air. Relative humidity, temperature, air flow rate and noodle properties are the most imperative factors that determine the drying rate of noodles. Due to the hygroscopic nature of salt, it significantly affects the diffusion of water during the process of drying. Noodles having lower concentration of salt could be dried quite easily compared to noodles with high salt concentration [1, 55].

The drying of noodles not performed properly could damage the structure of noodle resulting in cracking, splitting and over-elongation of noodle strands, which subsequently affect the handling and packaging process [1, 14]. Additionally, textural and cooking properties could also be affected severely. If the noodles are quickly dried, intense moisture gradient could result between the core and the noodle surface. When the noodles start to lose moisture, shrinking takes place. There occurs tension in the surface of noodle, while compression occurs in the core and finally resulted in deformation of noodle strands. Proper drying of noodles consists of multi-stages to avoid objectionable changes in the structure of the final product [1]. A common drying practice involves pre-drying, drying and cooling. The initial stage takes about 15 percent of the total drying time that involves a low temperature of 15 to 25 ^{o}C. The application of dry air at this stage causes lowering of moisture from 38% to below 28%. This step is important to dry the exterior of the noodle strands to avoid sticking and over-elongation of the noodle strands. Diffusion of core moisture takes place to the surface, and an equilibrium condition is attained between the surface moisture evaporation and the inside moisture diffusion. However, higher temperature of 40-50 ^{o}C and drier air of 55-60% relative humidity is given to eliminate the moisture in the second drying stage [1, 55]. Finally, the noodle strands is cooled down gradually and dried again. The gradual reduction in temperature is aimed to minimize the interior resistance in the noodle. The interest toward a healthier diet resulted in the development of hot air dried instant and steamed noodles, instead of fried noodles. Hot air is used to dry steamed noodles instead of frying to lower the water below 12 percent. They are dried by hot blast of air (70-80 ^{o}C) for a time period of 30-45 minutes [1, 5, 8, 14, 55-56].

3.6 Frying

After steaming process, instant noodles are mostly fried deeply. The strands of noodles are supplied to the frying baskets and are then dipped for deep-

frying in hot oil. Usually, the frying time and temperature are 60-100 seconds and 140-160 °C, respectively. The outlet of the fryer temperature is usually kept somewhat more than that of the inlet temperature [1]. Frying is maintained carefully in order to have minimum fat and fat decomposed products, as well as have good sensory properties, Deep-frying causes moisture loss, fat uptake and starch gelatinization, as well as formation of pores in noodle both externally and internally. The water in frying noodle migrates from the core to the surface. The steam vaporization in noodle during frying process created a porous sponge texture. Oil moves into the porous structure of the noodle strands from which steam flashes out. The mechanism of mass transfer during frying is dependent on the properties of steamed noodles, as well as frying time and temperature. The moisture and oil content of fried noodles are 15-22% and 3-6%, respectively. Water contributes an important role during heating, as it aids in providing thermal energy to the noodle strands in the hot frying oil. This transfer of heat from noodle surface avoids burning due to undue drying. During heating, the exchange of water to steam takes away large quantity of contacting oil energy from the system. Adequate heat should be provided in order to obtain full gelatinization that begun during the steaming process. The cooking of deeply fried instant noodles in boiling water resulted in the swelling of starch prior to the reduction of the moisture gradient. In contrast, the cooking of deep-fried noodle by means of steeping lead to the disappearance of moisture gradient in noodle strands before attaining sufficient starch swelling [1].

3.7 Boiling

The process of boiling is simple but very crucial in regard to quality attributes of the final product. The increase in popularity of refrigerated, frozen and shelf stable noodles in recent year resulted in the rise of using boiling process in manufacturing noodles. The important factor in boiling is time and water quality. The appropriate amount of boiling water must be 10 to 20 times greater than the weight of wet uncooked noodles. If the amount of boiling water is insufficient, then longer time is needed for processing and also the noodle strands stick together without enough relative movement in the boiling water, which lead to coarse texture and non-uniform strands during cooking [1]. In contrast, excess of boiling water or intense heating can damage the noodle strands owing to the greater friction among noodle strands and boiling water. The temperature of the boiling water is generally kept at 98 °C. However, boiling time is based upon the size and shape of the noodle strands and also the type of end products. Both boiling temperature and boiling time are adjusted carefully to give optimal textural attributes. Care should be taken during cooking to keep cooking loss to a minimum level. Higher rate of hydration, pre-gelatinization of starches and greater amount of salt concentration (up to 8%) reduce the boiling time in processing rice noodle, thereby minimizing the cooking loss. Boiling water having pH of 5–6 shows little solid loss. However, solid loss increases substantially when the pH of the boiling water reaches neutrality (pH 7–8). Therefore, the adjustment of pH from slightly acidic to neutral is necessary for boiling noodles. For this purpose, organic acids such as citric acid, acetic acid, malic acid or lactic acid are commonly used to control the pH of the boiling water in order to develop good quality boiled noodles [1].

3.8 Freezing

Boiled noodle texture deteriorates soon as a result of loss of moisture among the exterior and interior of noodle strands throughout storage period. The taste of boiled noodles can be extended through fast freezing. The absorption of water greater than 40% during dough mixing is important to facilitate the attainment of desirable and pleasing texture in the end products. Noodles with greater water absorption capacity minimizes the time needed for boiling of noodles. Blending of starches is also helpful in retaining boiled noodles texture during freezing. The noodles are dipped in cold water below 5 °C and then frozen quickly by blast of cold air at −30°C. The noodle strands can be separated easily during thawing if they are cooled to proper temperature (0−5 °C) before quick freezing. However, noodles frozen below −40 °C could spoil the structure of

noodle as a result of noodle core expansion during freezing by breaking the surface of the noodles, as it freezes fully prior to the freezing of noodle core [1].

4. QUALITY CHARACTERISTICS OF RICE BASED NOODLES

The quality attributes of noodles are established by considering the visual characteristics of cooked and uncooked rice noodles. The cooking properties such as high transparency, glossiness and absence of discoloration are the important factors for purchasing noodles by the consumers. Fine straight strands, translucency, whiteness and absence of broken strands are considered as the characteristics of premium quality and better priced noodles. The noodles must remain non-sticky, chewy and firm after cooking. Good quality rice noodles must cook quickly with little cooking loss [57]. Noodle qualities i.e. uniformity of shape, size, texture and color as well as nutritional, textural and cooking properties are the key criterion for evaluating rice noodles[1, 5, 7, 30, 56].

4.1 Proximate Composition

Proximate analysis of any food sample is conducted to determine the nutritional profile of that sample and also its amount by weight in the sample. The analysis is important in understanding the nutritional advantage of that specific product in the diet [50]. Some peoples are gluten intolerant (celiac disease) and wheat flour cause digestive malfunction. The only treatment is to exclude the intake of protein mostly found in barley, oats and wheat [54, 58]. Nowadays, consumers are interested in purchasing and consuming gluten free products, as these provide health benefits by inducing low glycemic index for diabetic patients; minimize chances of celiac diseases and other allergic reactions in gluten intolerant peoples [59].

The proximate analysis of rice flour i.e. moisture, protein, ash, crude fiber, fat, amylose and amylopectin concentrations varies significantly due to the variation in genetic makeup, environmental factors and milling process [5, 13, 50, 56]. A broad range of rice varieties are cultivated in the world that shows compositional variation among them. Noodles prepared from various rice varieties shows variation in quality characteristics [5]. It was reported that the moisture, ash, protein and fat concentration of dried rice noodles varied from 5.00-8.20%, 0.24–1.51%, 7.2–10.47% and 0.36–1.14%, respectively [55-56, 60]. Han et al. [50] studied the chemical composition of nine different rice varieties (Table 3). Protein concentration was found in the range of 6.92% to 8.65% in various rice varieties. While, the amylose concentration of rice varieties ranged from 10.13% to 32.07%. Juliano et al. [21] classified rice as low amylose (10-20%), intermediate (20-25%) and high amylose concentration (> 25%). Varietal differences were found in case of ash, lipid and starch concentrations, which might also be attributed to the processing such as milling [50]. These compositional differences influence the functional, thermal, cooking, eating and pasting properties of final noodles [61]. Starch is the main component of rice flour and has significant impact on the overall quality of noodle [62]. As gluten is absent in rice noodles; the pasting, thermal and physicochemical properties of the starches would be responsible for providing a quality noodle [63]. Rice flour provides smooth and creamy texture to noodles, which gives a clean taste [64]. On the other hand, Edwards et al [65]pointed out that increasing the concentration of smaller granule starches enhanced the elasticity and visco-elastic structure of the dough and also interpreted that this differences occurred in consequence of the interaction between protein and starch. Protein and lipids are present in substantial amount, which affect the properties of rice flour. It inhibits starch granules expansion during gelatinization and inhibiting retrogradation [62].The proximate composition (moisture, ash, protein, crud fiber) of rice noodles are also affected by rice bran. The moisture level increases with the increase of bran in rice noodles. However, higher the level of bran in rice noodles improved the protein and fat concentrations [66]. Intermediate amylose rice flour was used to develop soft texture noodles [23].Ordinary milled rice grains lack certain components, while brown rice contain germ and bran also, which provide certain health beneficial ingredients like vitamins, gamma amino

Table 3. Proximate composition of flour obtained from different rice varieties [50].

Variety	Proximate concentration (%)			
	Protein	Fat	Ash	Amylose
Jinsumi	7.35±0.09^{d}	1.26±0.01^{d}	0.60±0.02^{cd}	14.91±1.97^{d}
Manmibyeo	08.65±0.13^{a}	0.87±0.03^{f}	0.67±0.04^{b}	10.13±1.09^{e}
Hanareumbyeo	7.28±0.09^{d}	0.88±0.00^{f}	0.64±0.02^{bcd}	16.73±1.54^{d}
YR24088 Acp9	7.76±0.08^{b}	0.92±0.01^{e}	0.55±0.02^{e}	21.05±2.20^{c}
Seolgaeng	6.92±0.16^{e}	1.40±0.01^{c}	0.67±0.02^{b}	16.55±1.92^{d}
Milyang 261	7.65±0.04^{b}	1.66±0.01^{b}	0.65±0.03^{bc}	32.07±3.17^{a}
Suweon517	7.74±0.12^{b}	2.17±0.01^{a}	0.77±0.03^{a}	25.58±2.84^{b}
Chenmaai	8.61±0.05^{a}	0.63±0.01^{h}	0.60±0.02^{d}	23.43±1.44^{c}
Goamilbyeo	7.51±0.09^{c}	0.83±0.01^{g}	00.65±0.02^{bc}	024.54±2.41^{bc}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

butyric acid and dietary fibers [67-68].Rice varieties having high amylose concentration showed less starch lipid complex as compared to intermediate amylose containing rice [21].

4.2 Functional Properties

The functional properties of flour plays important role in product development, as it specify the quantity of water required to develop dough of optimum consistency and also represent the properties and behavior of the flour after hydration [69]. The functional properties such as water absorption index (WAI), swelling power (SP) and water solubility index (WSI) are of major concern [56]. Thumrongchote et al. [34] determined the functional properties of rice flour obtained from different varieties, which differed significantly, as given in table 4. The WAI indicate the ability of a food product to hold water [70]. Noodles manufactured from rice flour showed higher water absorption capacity compared to other cereal flours. It was observed from the previous literatures that the WAI of rice flour ranged from 3.3–8.0 g/g [34, 71]. On the other hand, Chandra and Samsher [72] found reasonably lower WAI (1.92 g/g) in rice flour. Ahmed et al. [56] blended wheat flour with rice flour and investigated its effect on the functional properties of noodles. The incorporation of wheat flour resulted reduction in WAI. A decreasing trend in WAI was found as the proportion of wheat flour in the blends increased. Similarly, it was observed in earlier studies, that the addition of wheat flour with rice flour caused a decrease in WAI of the flour blends [73-74]. The water absorption capacity of the flour is generally based on the variation in sources. It is also significantly influenced by the level of damaged starch. Higher the level of damaged starch, greater would be the water absorption capacity [37, 75]. Similarly, starch granule size also influence the water absorption capacity. The granule size of rice starch is very small compared to other cereal starches; therefore, it offers greater surface area for water absorption [13]. Rice flour having smaller particle size tends to release more amylose into the starch gel, which resulted in quick retrogradation. The gel hardness of flour is considered to be an important factor for noodle texture [7, 9]. The compositional variations in carbohydrate, protein, fat, fiber and amylose concentration of the flour lead to changes in WAI. Greater the percentage of starches and fibers in flour, higher would be the WAI [13, 72]. However, the WAI decreases in varieties containing high amylose [13, 76]. Similarly, the bonding between protein and starch also affects the hydration capacity of noodles. High protein concentration offers greater sites to make strong bond with starches, subsequently the water absorption capacity of noodles decreases [5, 77]. As the concentration of protein increases, the

Table 4. Functional properties of rice flour from different rice varieties at a temperature of 80 °C. [34].

Varieties	WAI (g/g)	WSI (%)	SP (g/g)
SuphanBuri 1	7.100 + 0.709^{ab}	0.909 + 0.211^{ab}	7.165 + 0.821^{ab}
SuphanBuri 2	6.684 + 0.694^{b}	0.727 + 0.104^{b}	6.734 + 1.008^{b}
SuphanBuri 3	8.008 + 0.317^{a}	1.068 + 0.098^{a}	8.095 + 0.315^{a}
PathumThani 1	6.838 + 0.365^{b}	0.787 + 0.063^{b}	6.892 + 0.368^{b}
SuphanBuri 60	6.477 + 0.451^{b}	0.897 + 0.181^{ab}	6.535 + 0.451^{b}
HawmSuphanBuri	6.909 + 0.220^{ab}	0.748 + 0.108^{b}	6.962 + 0.216^{b}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

optimum hydration of noodle dough minimizes and vice versa [78]. Lower water absorption lead to firm noodles as favored by most of the consumers [56].

On the other hand, the water solubility index of rice flour usually ranged from 0.6 to 7.94% [34, 71, 79]. However, the WSI of wheat flour is very low compared to rice flour [80]. A soluble loss of 0.04 to 0.12 g/g was found in rice based noodles [54]. There are many factors which influence the WSI of flour. Damaged granules showed highest WSI than normal granules. The degradation of granules occurs during dry milling of cereal grains 71, 80]. Similarly, rise in temperature also causes increase in WSI [79]. The composition of flour, i.e., protein and amylose concentration also effect WSI. Higher the amylose and protein concentration, lower would be the water solubility index of the flour [81]. Flour containing lower protein concentration leads to greater leaching of solids, which is attributed to the disintegration of the starch and protein network [46].Blending of wheat flour with rice flour resulted in lowering of water solubility index [56].

Swelling power is the other important functional property, which shows the capability of starch to absorb water under a specific cooking condition of 92.5 °C for 30 minutes. The swelling power of rice flour ranged from 5.82 to 16.23 g/g [5, 34, 79]. Hormdok and Noomhorm [9] found that the swelling power of rice starch was 10.54 g/g. Different factors such as milling methods, processing temperature, starch granules, protein; amylose and amylopectin concentration affect the swelling power of rice flour. Heo et al. [71] studied the influence of milling method (dry milling and wet milling) and temperature on the swelling power of rice flour. The SP of wet and dry milled rice flour at temperature of 25 °C and 100 °C were 3.8 g/g, 12.6 g/g and 4.7 g/g, 10.9 g/g, respectively. Thus it shows that processing temperature and milling method significantly influence the swelling power of rice flour. On the other hand, increase in protein concentration lead to a stiff starch/ protein complex. That causes a reduction in swelling power by restricting the starch granules to imbibe water, resulting in coarse and firm noodles [82-83]. Similarly, amylose and amylopectin concentration of the starch granules pose substantial influence on the swelling power of rice flour [84]. The degradation of starch granules due to various means (milling and processing) lead to the lowering of swelling power [7, 85]. When starch is heated above the gelatinization temperature in the presence of excess water; the starch granules swells due to water imbibitions, resulting in the leaching of starch components into the solution. The amount of solubilization and the degree of swelling depends on the chemical association within the granules [39]. High concentration of amylose and strong chemical bonds minimizes the swelling power by developing an extensive network [8]. Similarly, swelling power of rice flour is reduced with the increase in the concentration of wheat flour in the blends [56]. Techawipharat et al. [47] reported that waxy rice starch has higher swelling power and solubility compared to non-waxy rice starch. Normal rice starch is intact and rigid, which could not be ruptured easily compared to waxy rice starch. Amylose acts as an inhibitor as well as diluents to swelling, while amylopectin mainly affect the swelling power of starches and subsequently

influence the quality of noodles. Therefore, rice varieties with low amylose concentration give a high swelling volume [8, 30, 47]. Noodles prepared from flour with greater swelling power had softer texture [1].

4.3 Cooking Properties

Gluten is the most important factor for evaluating cooking quality. Gluten is formed on hydration of glutenin and gliadin which provide elastic and extensive texture to the dough. It minimizes stickiness and solid loss and provides firmer texture to the product [6].However, due to the lack of gluten in rice flour, some technological problem arises. So, it requires proper processing techniques and additives to modify the characteristics of starch and protein [86]. For this purpose, rice flour is pre-gelatinized that performs same function as gluten, thereby provides firm structure and avoids stickiness after cooking [86-87]. Cooking quality of rice flour depends on the genetic and environmental factors [88]. Cooking time, cooked weight, cooking loss and percent rehydration are important factors that determine the cooking properties of noodles. Lower cooking time and slight loss of solids in cooking water are prominent features of good quality noodles [80].Rice flour obtained from freshly harvested rice is usually soft and sticky compared to flour from aged rice. It is therefore important to keep harvested rice for certain period to aid in processing. During storage, changes in physical and chemical properties are observed, which influence the cooking quality of rice, especially its flavor, texture and product quality after processing. Certainly, any product, such as noodles prepared from aged rice will give less sticky texture [44-45]. Charutigon et al. [89] reported that noodle prepared from rice flour had white color but stuck together after cooking process. They further suggested that using mono-glyceride and modified starches could minimize the stickiness of cooked noodles.

The cooking time of rice based noodle is measured by cutting the oven dried noodle samples (1 gm) to about 2.0 cm length. The noodle strands are cooked by occasional stirring in a beaker having boiling water. Optimum cooking time of rice noodle is assessed by squeezing together the noodle strands between glass slides and monitoring the time of fading away of the white core of noodle strands that indicates the time of cooking [5, 56]. Usually, rice based noodles takes 5 to 9 minutes to cook [5, 9, 56]. The cooking time of rice based noodle is influenced by their higher water absorption index as compared to wheat based noodles. It is because of their smaller starch granules, which provide higher surface area for hydration that reduces the gelatinization temperature and cooking time [62]. Cooking time is also influenced by the type of starch used and the thickness of noodles strands. It is observed that thin noodle strands have short cooking time due to greater surface area for diffusion of water [7, 62].Compared to wheat based noodles, rice noodles have lower cooking time due to pre gelatinization of rice flour and higher water absorption index [86-87].Addition of various starches at different level to rice flour effected the cooking time of rice based noodles, which in turn affected the final texture of noodles. Noodles made from rice flour showed lower cooking time values compared to noodles made from canna starches, mung- bean starches and sweet potato starches. This difference was attributed to the different gelatinization temperature of each starch [22].

The cooked weight of noodle is determined by taking weight of the wet mass of noodles [5, 56]. Rice based noodles showed higher cooked weight as compared to wheat based noodles. The higher pasting viscosity, swelling power and lower amylose concentration of rice starch granules is responsible for higher cooked weight of rice noodles [22, 80]. Sandhu and Kaur (2010) found lower cooked weight for rice starch noodle than that of potato starch noodles. This variation in cooked weight might be attributed to the differences in swelling power and viscosities of these starches. A positive correlation was observed between water absorption index and damaged starch level [75], as cooked weight is the rise in the weight of noodle after cooking by the absorption of water [91]. While, percent rehydration is the relative proportion of weight of cooked noodles and uncooked noodles, that may influence the noodle eating quality (5). Researchers found percent rehydration of146 to 290% in rice based noodles [9, 22]. The rehydration ratio influences the cooking and textural properties of the noodles. High

rehydration rate in rice based noodles provided a sticky and soft noodle. However, lower rehydration rate lead to a course and hard noodle texture [7, 52]. Percent rehydration showed a negative correlation with solubility and showed positive correlation with PV, CPV, HPV, setback and consistency [8]. Rice noodles showed greater rehydration ratio as compared to starch based noodles, which might be due to the variation in swelling power and their respective pasting properties [9, 22].

Cooking loss is the sum total of solid loss in cooking water [54], which is due to the solubility of starches in boiling water. It is the most prominent factor that determines the cooking quality of final product and illustrates the capability of a product to offer resistance to the structural breakdown while cooking [4]. It was observed form the previous literatures that the cooking loss values of rice based noodle ranged from 0.06–0.19 g/g [5, 22, 55, 71]. Similarly, cooking loss values ranging from 0.27% to 0.74% was recorded in various rice genotypes [8]. In contrast, Sandhu and Kaur[90] observed a relatively higher cooking loss (1.53%) in case of rice starch noodles. Ahmed et al. [56] reported significant difference in cooking loss values in noodles prepared from various blends of rice and wheat flours. Noodles made from broken rice flour/ wheat flour (60:40) showed highest cooking loss, while pure wheat flour noodle showed lowest cooking loss. However, the cooking loss value increased significantly by incorporating other starches in rice flour [55]. Noodle made from wet milled rice flour showed lower cooking loss as compared to noodles made from dry milled rice flour, that is attributed to the lower water solubility of wet milled rice flour as caused by due to lower level of damaged starch [1, 50, 71]. Amylose concentration negatively influences the cooking loss of rice noodles. Noodles containing low amylose concentration lead to higher cooking loss and vice versa [5, 23, 50]. Cooking loss showed negative correlation with CPV, HPV, setback and consistency except PV [8]. Cooking loss significantly influence the sensory properties of cooked noodle samples. The loss of solid in cooking water is influenced by variation in cooking time, protein and amylose concentrations of different rice varieties used [5, 7].It is very important to uphold the structural integrity of noodles during the cooking process. Higher loss of solids in cooking water resulted in undesirable noodles characteristics such as poor cooking tolerance or resistance, high starch solubility, which lead to sticky mouth feel [8, 71, 90, 92].

4.4 Textural Properties

Textural attributes of cooked noodles are evaluated by the mouth feel of the noodles and their resistance to chewing. A number of instruments are available for measuring the texture of noodle, as an alternative to sensory analysis [50].Textural property of rice noodle is based on flour pasting properties, swelling power and gel hardness [8]. All these physicochemical properties effect textural quality of cooked noodle, which is directly related with consumer acceptance [9]. Texture of cooked noodle is one the most critical attribute which shows consumer acceptance [50]. It is a unique property which is influenced by many ingredients like protein, water, starch and hydrocolloids that play vital role in describing the textural characteristics. The water absorption index is one of the most important factors which impart significant role on textural properties of noodles [93]. The eating quality of cooked noodles is related to cohesiveness, hardness and chewiness [94].

The texture of noodle is assessed by the help of tensile testing, firmness and recovery. Tensile testing is assessed by the establishing the breaking strength and broken length of the noodle strands. Both of these properties are interrelated and indicate the resistance of noodle strands to breakage [95]. It also reflects the way noodle swells and breaks during cooking and indicates the cooking quality and cooking tolerance of noodles. While, the distance it take prior to the breakage of noodle strands measures the extensibility [5, 13, 95]. Fari et al. [5] studied the textural characteristics of cooked rice noodles made from different rice varieties (Table 5).The tensile strength of the noodle samples prepared from various rice varieties ranged from 8.0 to 16.7kPa. On the other hand, extensibility of the noodle strands ranged from 6.0 to 11.8kPa. While, the elastic recovery and firmness of rice noodles ranged from 26.2-52.2% and 85.8-89.0%,

respectively [5]. The noodles having lowest value for tensile strength entailed little time to break, which shows their less extensibility. Noodles made from high amylose rice varieties showed greater tensile strength and extensibility. It was observed that the tensile strength is positively correlated with amylose concentration. As the concentration of amylose increased, the noodle samples exhibited difficulty in breaking and stretching. Noodles with higher elastic recovery and firmness lead to good quality noodles with little solid loss in cooking water [5, 8, 92]. Tensile strength shows the ability of noodles to withstand a force applied longitudinally without tearing. Tensile strength shows the cooking behavior of the noodles, as it gives indication of noodle integrity during cooking. While, elasticity shows the capability of the deformed noodles to gain its original shape and size after the removal of applied force[8]. Thomas et al. [14] studied the tensile strength and elasticity of noodles prepared from Bario rice and Basmati rice. Noodles made from Bario rice showed higher tensile strength (46.33 kPa) as compared with Basmati rice (36.33 kPa) on initial day. While the tensile strength of noodles decreased after 3 days of storage at room temperature both in Bario and Basmati rice noodles. The amylose concentration of Bario rice was higher as compared to Basmati rice, which significantly affects the tensile strength of cooked noodle. However, the elasticity modulus of Bario rice noodle was higher (13.19kPa) than Basmati rice noodle (7.89kPa) after 3 days of storage period. The elasticity modulus decreases significantly in rice noodle after storage [14, 92].

Nura et al. [13] observed that variation in flour particle size affected the textural properties of laska noodle. Springiness, chewiness and hardness of laska noodles made from flour of smaller particle size were comparatively higher than noodles made from flour of larger particle size, characterizing better quality. Similarly, Yoenyongbuddhagal and Noomhorm [7] and Hatcher et al. [96]observed that the fine flour improves the textural properties of noodles, which is due to the quick and almost complete gelatinization of smaller particle size. Similarly, more water and heat is entered into the starch granule cores of the flours with fine particle size. The increase in paste viscosities for finer rice flour represents an increase in gelatinized starch. The higher proportion of gelatinized starch is important for rice noodle texture, since it acts as a binding agent during extrusion. Hence, the smaller particle size rice flour produces better quality noodle [1, 13]. The textural attribute of noodles is influenced primarily by proteins, fibers, starch/protein network and other supplementary constituents [60]. Rice noodles having lower amylose concentration showed higher adhesiveness, which showed the higher stickiness of the cooked noodles. However, lower adhesiveness is an indication of quality rice noodle, as it gives a clean and smooth texture [50].

4.5 Sensory Properties

Consumers usually purchase noodles from either local manufacturers or convenience stores. Their

Table 5. Textural properties of cooked rice noodles made from different rice varieties [5].

Varieties	Extensibility (mm)	Tensile strength (g)	Firmness (%)	Elastic recovery (%)
Bg 300	11.8 ± 2.5^{a}	13.2 ± 3.8^{b}	87.9 ± 2.4^{ab}	46.6 ± 8.2^{a}
Bg 352	11.4 ± 2.3^{a}	16.7 ± 3.4^{a}	8.6 ± 2.7^{a}	50.3 ± 6.1^{a}
Bg 94-1	9.2 ± 3.1^{b}	12.1 ± 4.6^{b}	88.2 ± 3.4^{ab}	48.6 ± 8.5^{a}
Bg 403	11.8 ± 2.1^{a}	12.2 ± 2.3^{b}	85.8 ± 3.9^{b}	37.3 ± 9.0^{b}
At 306	6.0 ± 1.8^{c}	13.5 ± 3.0^{b}	88.5 ± 3.1^{a}	52.2 ± 14.5^{a}
At 405	6.1 ± 1.6^{c}	8.0 ± 1.7^{c}	86.7 ± 2.6^{ab}	26.2 ± 5.4^{c}
Bw 272-6b	10.3 ± 1.5^{ab}	11.9 ± 3.3^{b}	87.6 ± 1.1^{ab}	49.4 ± 12.6^{a}
Ld 356	10.2 ± 2.6^{ab}	10.7 ± 3.6^{bc}	89.0 ± 1.4^{a}	35.6 ± 10.3^{b}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

Table 6. Sensory attributes of Laska noodle prepared from rice flours with different particle sizes using 9-point hedonic scale [13].

Particle size (µm)	Appearance	Aroma	Taste	Texture	Overall acceptability
140	4.30±1.58^{e}	6.00±1.57^{a}	5.14±1.74^{b}	3.66±1.73^{e}	3.98±1.61^{e}
125	5.14±1.40^{d}	5.74±1.52^{a}	5.24±1.48^{b}	4.44±1.46^{d}	4.80±1.46^{d}
100	5.76±1.32^{c}	5.58±1.75^{a}	5.36±1.60^{b}	5.22±1.48^{c}	5.56±1.36^{c}
80	6.44±1.18^{b}	5.64±1.69^{a}	5.80±1.46^{ab}	6.24±1.39^{b}	6.36±1.17^{b}
≤63	7.32±1.13^{a}	5.74±1.93^{a}	6.12±1.45^{a}	6.92±1.26^{a}	7.02±1.12^{a}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

purchasing decisions are mainly based upon the preliminary judgment of the noodle quality visually such as brightness, absence of undesirable specks and color [97]. The sensory attributes of cooked rice noodles are appearance, aroma, taste, texture and overall acceptability [5, 56]. Preference for each sensory characteristics varies from one consumer to another; some like raw milled rice and aromatic rice, others prefer conventional rice or the parboiled rice [98].These properties are significantly influenced by using various varieties of rice for noodle production. The sensory properties of final noodle products are evaluated by trained sensory panels [5]. The most important quality factors in this regards are texture and color of final product [15, 99]. Consumers mostly prefer hard and non-sticky noodles which are influenced by the flour amylose concentration [5, 15, 99]. The sensory attributes of cooked rice noodle is also influenced due to the variation in flour particle size (Table 6).

The important factor in the evaluation of rice noodle product is appearance. The appearance of noodle manufactured from rice flours exhibited variations, which is credited to the presence of natural pigments, i.e., polyphenols and carotenoids [100]. Color is the most important parameter used for evaluating the visual quality and is important for better marketability of noodles. Fresh noodles must maintain white colored appearance [101]. Appearance is also influenced by the interaction of starch and protein. As the interaction between protein and starch is weak, it gives opaque noodles. An increase in ash concentration also affects negatively the appearance of noodles. As ash concentration of the final noodle is less, it gives transparent product [102].The sensory scores obtained in case of appearance property of rice noodles varied from 3.5 to 7.32 on a 9-point hedonic scale [5, 13, 34-35, 65]. Thomas et al. [14] evaluated the appearance of Bario rice and Basmati rice. The appearance of Bario rice scored higher as compared to Basmati rice (6.8 and 4.3, respectively).Wheat flour is sometime blended with rice flour in order to improve the cooking and sensory properties of rice noodles [61, 100]. The first parameter assessed by the consumer in food product is color, so the evaluation of visual color as part of sensory attribute is very crucial [97].

Another important sensory property assessed is flavor, which influences the amount of food consumed by the consumer. Usually the aroma of noodle product is determined by subjective evaluation. Aroma is evaluated subjectively based on the experience of panelists by smelling. Thomas et al [14] found slightly higher acceptance rate in case of aroma of noodle made from Basmati rice (5.87) than Bario rice (5.73). Previous literature showed a sensory liking score for taste of rice noodle in the range of 5.1 to 6.7[5, 13, 103]. The panelists observed little variation in the score for taste of rice noodle samples [13].However, rice noodle blended with wheat flour showed higher acceptance (6.18−7.48) in term of aroma [86]. The aroma of cooked product is generally considered a minor quality factor than other sensory properties (taste, texture, color, etc.), as it minimally affect the consumer choice for accepting a product [5].

Texture is an important quality factor for accepting the product in the marketplace. Texture is defined as the property of food structure that can be observed in response to the applied force. The texture of rice based noodle is affected by rice

variety, processing factor, amylose concentration and gelatinization temperature [5, 9]. On a 9-point hedonic scale, the sensory liking scores cooked rice noodle in term of texture ranged from 3.11 to 6.92 [5, 13, 55]. Wang et al. [104] found that rice noodle scored highest in case of hardness, while lowest score in case of slipperiness. The mean scores of native rice noodles as well as their blends with wheat flour differed significantly in regard to texture [56]. Rice noodles made from the incorporation of wheat flour in a considerable amount give desirable texture [56]. Similarly, Inglettet al. [48] found similar trend in noodles prepared from blend of rice and wheat flour. Texture is the main quality factor that determines consumer preference for the cooked noodle [105]. High quality noodle must be neither too hard nor too soft [22, 57]. Texture of rice noodle is also affected by particle size. The acceptance rate of noodles made from flour of small particle size was more as compared to the flour of large particle size [13]. Muhammad et al. [106] evaluated the stickiness, elasticity and taste of cooked rice noodles by twenty trained panelists. The noodle stickiness was judged by testing the adherence of the noodles to the tongue. While the noodle elasticity was evaluated by stretching the noodle strands until they break. The reduction in firmness is due to the lower level of protein in rice noodle as compared to wheat based noodles [107]. Generally, rice based noodles have soft, and sticky texture with lower elasticity [22]. Firmness is the main factor in representing the texture of cooked noodles [1, 5].

The overall acceptability of rice noodles depends upon appearance, aroma, taste and texture. Various researchers have found differences in the desirability and acceptance of rice based noodles. Overall acceptability score values of rice noodles on 9-point hedonic scale were in the range of 2.7 to 7.02 [5, 13, 55]. Rice noodles blended with wheat flour showed maximum acceptance scores [35, 66]. Thomas *et al.* [14] studied the sensory acceptance rate of Bario and Basmati rice noodles. Bario rice had a higher acceptability score of 6.67 compared with Basmati rice (4.8). In term of appearance and overall acceptability, noodles made from Bario rice were ranked higher as compared to Basmati rice noodles. It was observed that panelists usually give preference to firm noodle irrespective of the aroma [5]. The cooking loss of rice noodle negatively correlated with the sensory properties of noodles [71]. Maximum cooking loss causes turbidity in cooking water; thereby decreases cooking tolerance and mouth feel [56, 82]. It was observed form the previous literatures that variation in genetic makeup of rice as well as flour particle size contribute important role in final noodle acceptance [5, 13].

5. CONCLUSIONS

Recently, demand for gluten free noodles in the diet has increased due to their health beneficial effect. It reduces allergic reactions and celiac diseases in peoples, who suffer from such problems by eating wheat based products. Flour, water and salts are the fundamental ingredients that are used to prepare rice noodles. Sometime, additional ingredients i.e. emulsifiers, starches, stabilizer and colorings are added to improve the functional, physicochemical, cooking and sensory attributes of rice based noodles. The basic processes involved in the development of rice noodle involve dough mixing, sheet forming, compounding, sheeting/reduction, steaming and cutting. The variation in flour properties and processing method imparts significant role in final noodle quality. Rice based noodles are made from rice flour having appropriate protein and amylose concentration and lower ash concentration. Compositional differences and lower starch concentration influence the functional, thermal, pasting, cooking, eating and sensory properties of rice noodles. Protein concentration and amylose concentration have a positive correlation with the firmness and brightness of the noodle strands. Higher level of starch causes excessive surface swelling and cooking loss. On the other hand, ash concentrations negatively affect the brightness of noodle. Therefore, appropriate amount of these components in flours are preferred to prepare noodle with appropriate cooking and textural properties. High quality rice noodle must have appropriate textural, cooking and sensory properties with extended shelf life without microbial spoilage and oxidative rancidity.

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Pakistan Academy of Sciences

Obituary

Prof. Dr. Nasir-ud-Din
(1937–2016)

We are grieved on the sad demise of an eminent scientist and a senior Fellow of the Pakistan Academy of Sciences, Prof. Dr. Nasir-ud-Din, who breathed his last in Lahore on Thursday, 18th February, 2016. He was elected Fellow of the Pakistan Academy of Sciences in 1996.

Prof. Dr. Nasir-ud-Din was born in Amritsar, British India on 15th August, 1937. He obtained his BSc in 1955 and MSc in 1957 from University of the Punjab, Lahore. Later, he earned PhD from Edinburgh University, Scotland in 1963. In 1996, Prof. Dr. Nasir-ud-Din was conferred DSc by his alma mater, i.e., Edinburgh University, Scotland.

Prof. Dr. Nasir-ud-Din was Chairman, Institute of Molecular Sciences & Bioinformatics, Lahore since 2000, till his demise. Earlier, he had served as Professor of Biochemistry and Dean, Postgraduate Studies and Research, The Lahore University; Executive Director, Institute of Biomedical Sciences, Lahore; Adjunct Professor, H.E.J. Research Institute of Chemistry, University of Karachi, Karachi; Visiting Professor, Georgetown University, Washington, DC, USA; University of Geneva, Switzerland and Harvard University, Cambridge, USA. In University of Balochistan, Quetta, Prof. Nasir-ud-Din had served as Director, Institute of Biochemistry; Professor and Chairman, Department of Chemistry/ Biochemistry. He was Visiting Scientist, Institute National de la Sante et de la Recherche Medicale, Unite de Recherches sur la Biochimie des Proteines, Lille, France; Assistant Biochemist, Department of Medicine, Massachusetts General Hospital, Boston, USA; Research Fellow in Biochemistry, Massachusetts General Hospital, Boston, USA; Technical Director (Advisor), Johnson & Johnson Pakistan, Karachi; Chief Chemist and Manager Quality Control, Johnson & Johnson Pakistan, Karachi; Lecturer, University of the Punjab, Lahore; Research Fellow, Biological Chemistry, Harvard Medical School, Harvard University, Cambridge, USA; Demonstrator, Chemistry Department, Edinburgh University, Scotland; and Demonstrator, Institute of Chemistry, University of the Punjab, Lahore.

Prof. Dr. Nasir-ud-Din was Fellow of Pakistan Institute of Chemists; The Academy of Sciences for the Developing World (TWAS); Pakistan Society of Biochemistry and Molecular Biology; and Chemical Society of Pakistan. Also, he was Member of Pakistan Biological Sciences Society; Pakistan Institute of Chemists; and Chemical Society of Pakistan.

In recognition of his outstanding contributions in the field of chemistry/biochemisty, Prof. Dr. Nasir-ud-Din was conferred Edinburgh University, Studentship, 1961; Fulbright-Hays Award, 1963; Senior Fulbright-Hays Award, 1969; *Sitara-i-Imtiaz,* Govt. of Pakistan, 1991; Gold Medal (B. Khan), University of Balochistan, Quetta, 1992; Visiting Scientist Award, World Health Organization, 1989; and Visiting Scientist Award, National Medical Research Institute, France, 1982.

Prof. Dr. Nasir-ud-Din's areas of research were Biochemistry, Chemistry, Immunology of Complex Carbohydrates; Structure-Function Relationship of Glycoproteins; Secretory Proteins, Glycoproteins of Epithelial Cells and Cell Surface Carbohydrates; and Malaria Glycoproteins.

Prof. Dr. Nasir-ud-Din was a kind and humble person, and, despite health problems, remained committed to his scientific pursuits till his demise. In the death of Prof. Dr. Nasir-ud-Din, Pakistan has lost a committed and accomplished scientist. May Allah Almighty rest his soul in eternal peace and give fortitude to his family to bear this irreparable loss! Aameen.

Dr. Abdul Rashid, *FPAS*

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RESULTS: Be clear and concise with the help of appropriate Tables, Figures and other illustrations. Data should not be repeated in Tables and Figures, but must be supported with statistics.

DISCUSSION: Provide interpretation of the RESULTS in the light of previous relevant studies, citing published references.

ACKNOWLEDGEMENTS (font size 10)**:** In a brief statement, acknowledge financial support and other assistance.

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2. Bialek, W. & S. Setayeshgar. Cooperative sensitivity and noise in biochemical signaling. *Physical Review Letters* 100**:** 258–263 (2008).
3. Kay, R.R. & C.R.L. Thompson. Forming patterns in development without morphogen gradients: differentiation and sorting. *Cold Spring Harbor Perspectives in Biology* 1: doi: 10.1101/cshperspect.a001503 (2009).

b. **Books**

4. Luellen, W.R. *Fine-Tuning Your Writing*. Wise Owl Publishing Company, Madison, WI, USA (2001).
5. Alon, U. & D.N. Wegner (Ed.). *An Introduction to Systems Biology: Design Principles of Biological Circuits*. Chapman & Hall/CRC, Boca Raton, FL, USA (2006).

c. **Book Chapters**

6. Sarnthein, M.S. & J.D. Stanford. Basal sauropodomorpha: historical and recent phylogenetic developments. In: *The Northern North Atlantic: A Changing Environment.* Schafer, P.R. & W. Schluter (Ed.), Springer, Berlin, Germany, p. 365–410 (2000).
7. Smolen, J.E. & L.A. Boxer. Functions of Europhiles. In: *Hematology, 4th ed*. Williams, W.J., E. Butler & M.A. Litchman (Ed.), McGraw Hill, New York, USA, p. 103–101 (1991).

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