

Full Length Research Paper

Distribution of nitrate in the water resources of Pakistan

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Water quality monitoring activities have recognized the nitrate contamination in the drinking water sources as one of the major quality issue of Pakistan. Adopting a uniform sampling design, 747 samples were collected from a wide range of irrigated or non-irrigated regions having distribution of samples in sixteen cities as Lahore (79), Kasur (46), Faisalabad (30), Khushab (50), Chakwal (51), Mianwali (30), Jhelum (53), Bahawalpur (60), Karachi (60), Mirpur Khas (55), Peshawar (38), Risalpur (35), Quetta (81), Ziarat (21), Loralai (21), Mastung (37). The results showed that 19% of the total samples have nitrate concentration beyond the permissible safe limit of 10 mg/L falling in the concentration range of 11-160 mg/L of nitrate. The highest percentage contamination (23%) is found in water samples collected from both the Balochistan and Punjab provinces. Comparatively higher nitrate levels of <70 % in the groundwater sources like hand pumps and wells support the possibilities of increased contamination in the areas cultivated using heavy doses of fertilizers. Findings of the study provide support for further epidemiological investigations and potential strategy for mitigating the issue in the affected regions.

Key words: Nitrate-N, groundwater contamination, hand pumps, methemoglobinemia, Pollution, nutrients, fertilizer, agriculture.

INTRODUCTION

Pakistan has a marked decline in its per capita water availability from 5600 to 1,000 m³ (Kahlowan et al., 2001) which resulted in deteriorated quantity and quality of surface and groundwater as the quantity and quality of water are in direct proportion. The reasons of poor quality of water may be untreated disposal of municipal and Industrial effluents, excessive use of fertilizers and insecticides. In addition, out of the total, 40% of diseases (The Network for Consumer Protection in Pakistan and Action aid Pakistan, 2002) prevalent in the country are water borne and 20 - 40% hospitalizations are due to such water borne diseases. Therefore, considering the demand of the time, Pakistan Council of Research in Water Resources (PCRWR) launched a National Water Quality Monitoring Programme (2001 - 2006) in the country and the findings of this mega water quality monitoring program for 24 major cities of Pakistan has recognized the existence of four major water quality problems such as

bacteriological contamination (68%), arsenic (24%), nitrate (13%) and fluoride (5%) in the surface or groundwater sources. In the back drop of these findings, various investigative studies to seek the detailed profile of nitrate in the water sources were conducted as the major sources of nitrate contamination of surface and ground water are fertilizers, animal wastes, septic tanks, municipal sewage treatment systems, and decaying plant debris. Other sources of nitrate contamination of water include intensive livestock operations that produce large amounts of animal waste, sub-standard human septic systems and municipal waste streams. Shallow and poorly constructed wells in rural areas of Pakistan are at greatest risk of nitrate contamination. Drinking water being the main source, other sources of inorganic nitrate exposure to children and adults are considered to be vegetables (spinach, cabbage and carrots), meat preservatives, burn creams, industrial salts and cold packs (anticorrosives). Sources of organic nitrate include inhalants, room deodorizers, pharmaceuticals, laundry ink, industrial solvents and antibiotics. The Indus basin, covers more than 566 000 km² (or 71% of the territory), comprising the whole of the provinces of Punjab, Sindh

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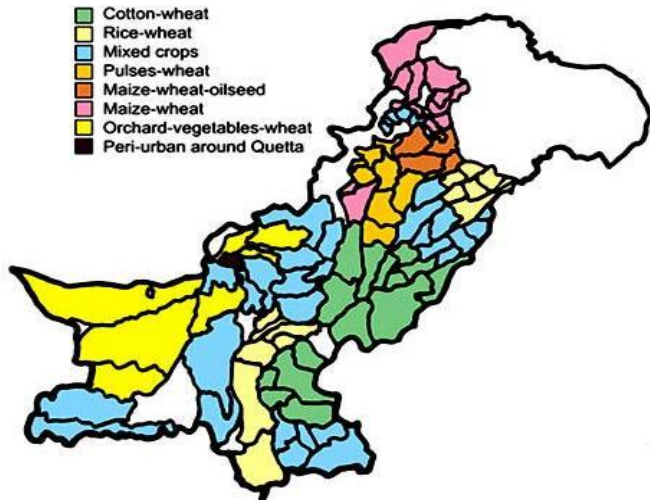


Figure 1. Crop production regions of Pakistan.

and NWFP as well as the eastern part of Balochistan. The Kharan desert of Balochistan (in the west of the country), which is an endorheic basin covering 15% of the territory. The arid Makran coast in Balochistan Province along the Arabian Sea covers 14% of the territory in its southwestern part. Total water withdrawal in 2001 was estimated at 166 km³, of which 95.6% is used for agricultural purposes (4.4% is withdrawn for domestic use and another 1.6% for industrial use). Groundwater abstraction for agriculture has been roughly estimated at 63 km³/year through more than 500,000 tube wells. However, in some areas, development appears to have reached the point where groundwater is being mined. Over 50% of the village water supply is obtained through hand pumps installed by private households. In saline groundwater areas, irrigation canals are the main source of domestic water. The total irrigated area of the country is 18 million ha whereas about 4 million ha is rain fed. The main irrigated crops are wheat, rice, sugar cane and cotton as exhibited in Figure 1.

Nitrate refers to a large family of nitrogen-containing organic and inorganic compounds. Chemistry of nitrate as nitrogen is a wide subject due to its number of natural and man-made sources for the release into the environment. Nitrate from drinking water accounts for 15 - 75% of person's exposure to nitrate from environmental sources (Vladeva et al., 2000). The main health effect of nitrate ingestion is a blood disorder called "methemoglobinemia" also known as "blue baby syndrome" (National Center for Environmental Health), Children exposed to high levels of nitrate in drinking water may also be at increased risks for developing goiter and respiratory tract infections (Gupta et al., 2000; Weyer et al., 2001). Studies have also suggested that nitrate in drinking water may be linked with increased risk for bladder and ovarian cancer, non-Hodgkin's lymphoma, genotoxic effects at chromosomal level and insulin dependent diabetes (Ward

et al., 1996).

Preliminary work was carried out to identify the ground water contamination of nitrate in the irrigated areas of Pakistan (Latif et al., 1999) as the provinces of Punjab and Sindh, in the east and south, is well irrigated by the Indus and its tributaries. Similar type of studies was carried out in the rural areas of Rawalpindi and Islamabad (Tahir et al., 1998; Sajjad et al., 1998). Considering the wide application of bio or commercial fertilizers and the lack of detailed data in context to nitrate contamination from the whole country, it becomes essential to know the details regarding the nitrate content of the water sources and thus the present study has the aim of evaluating nitrate levels in the wide range of irrigated and non irrigated regions of the country.

MATERIAL AND METHODS

Seven hundred and forty seven water samples were collected from various surface or groundwater sources such as hand pumps, tube wells, wells, nullahs, springs, dams, bores and water supply of sixteen major cities of the country on the basis of grid size of 0.25 km² for small cities, 9 km² for medium cities and 16 km² for big cities. Following the grids on the city maps, one sample per grid was taken maintaining a distance of 0.5 or 1 km between two monitoring points. Replicating every fifth sample for quality control purpose, 298 samples were collected additionally to check the reliability and accuracy of the sampling procedure as well as analytical results.

Following the Standard Methods (Standard Method for Examination of Water and Waste Water, 1992) all the samples were collected in ½ liter polystyrene bottles having 5 ml of 1 M Boric acid as preservative. Necessary information regarding sampling was recorded in the sampling Proforma whereas all the samples were analyzed for Nitrate-Nitrogen (NO₃⁻-N) in the laboratory by Ion Selective Electrode Method on Ion Meter (Model-3345, Jenway England). A sample of blank, known nitrate standard and previously analyzed sample were analyzed after every ten samples to check the reproducibility of method and their results were found in the range of ± 5% deviation than the actual analysis.

RESULTS AND DISCUSSIONS

Analytical data was compared with WHO guidelines value for nitrate that is, 10 mg/l in order to evaluate the status of nitrate contamination (WHO, 1996a; WHO, 1996b). Out of 399 total samples from eight cities of Punjab province, 90 samples (23%) have shown unsafe levels of nitrate as presented in Figure 2. Whereas Chakwal city has shown higher %age contamination followed by Kasur, Faisalabad, Mianwali and Jhelum cities (Figure 3). Only 8 out of total 115 sources (7%) selected from Sindh province have shown unsafe nitrate level with higher percentage contamination in Karachi city (8%) as presented in Figures 4 and 5. 90% of water sources of NWFP were found free from nitrate (Figure 6) as 7 samples were found beyond the permissible limits of WHO. However, Peshawar city had 18.4% nitrate pollution in its water sources as presented in Figure 7.

Out of 160 water sources of Balochistan province, 32

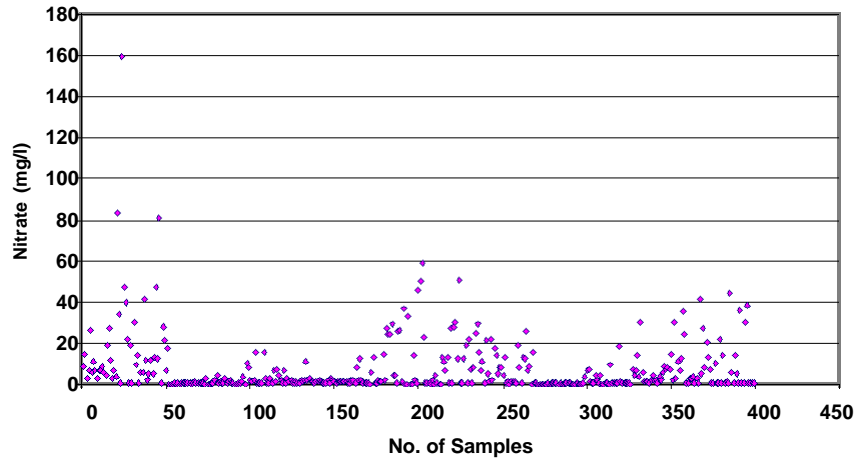


Figure 2. Variation in nitrate concentration (mg/l) in Punjab province.

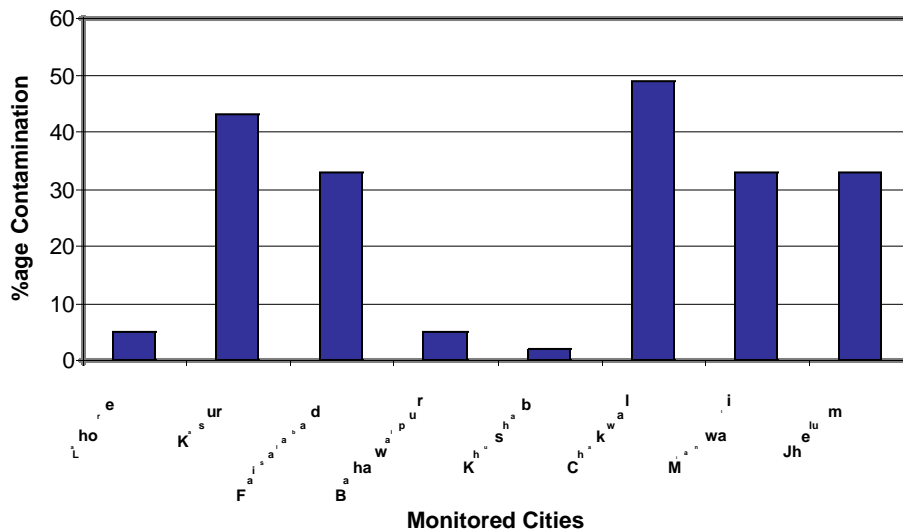


Figure 3. Percentage contamination in Punjab province.

locations (23%) had shown nitrate contents exceeding WHO guideline values with higher contamination level in the water sources of Ziarat city when compared to other three cities as presented in Figures 8 and 9.

In overall, 19% locations of the country out of total 747 monitored for presence of nitrate had indicated unsafe nitrate contents (11 - 160 mg/l) with highest contamination (23%) in Balochistan and Punjab provinces. The highest nitrate concentration value of 160 mg/l is discovered in a hand pump source of District Chakwal of Punjab province and it may be possible because of extensive fertilizer application and presence of stagnant sewage pond as observed during sampling and information recorded on field perform. Presence of nitrate has also been identified as the fourth most potential contaminant in the water resources of the country revealed by the

findings of National Water Quality Monitoring Program (Kahlowan et al., 2004) . A comparison of the results of all the five phases of this monitoring program has indicted a fluctuation in nitrate level of monitored cities. Nitrate levels in groundwater may fluctuate widely throughout the year, depending on precipitation, soil types and other factors. Consequently, short term nitrate concentrations can reach levels many times higher than WHO health based guideline values, particularly during the growing season when fertilizers are heavily applied. Pakistan is an agricultural country and 96% of its total water re-sources are being used by agriculture sector, Fertilizer consumption has increased threefold during the past 30 years in the country. It reached one million nutrient tonnes in 1980 - 1981, two million tonnes in 1992 - 1993 and three million tonnes in 2002/2003 (FAO, 2007).

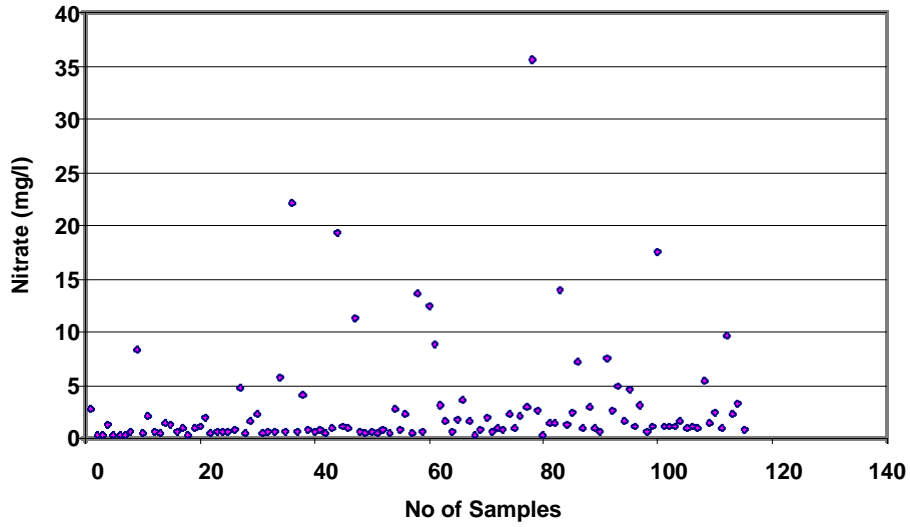


Figure 4. Variation in nitrate concentration (mg/l) in Sindh province.

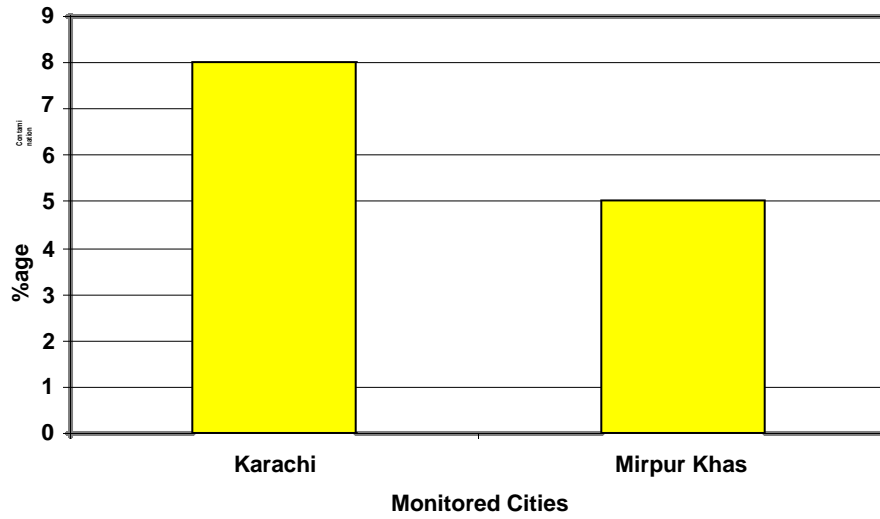


Figure 5. Percentage contaminations in Sindh province.

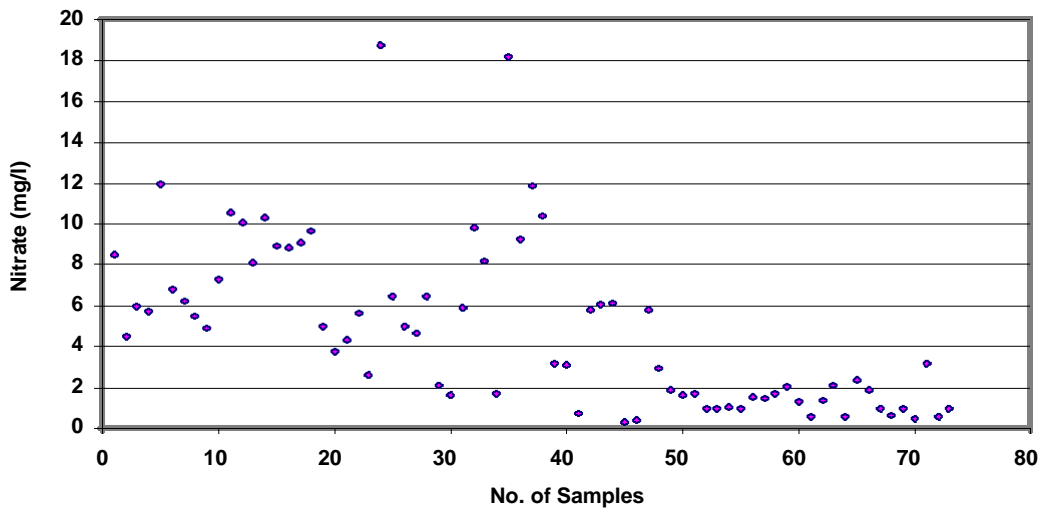


Figure 6. Variation in nitrate concentration (mg/l) in North West Frontier Province (NWFP).

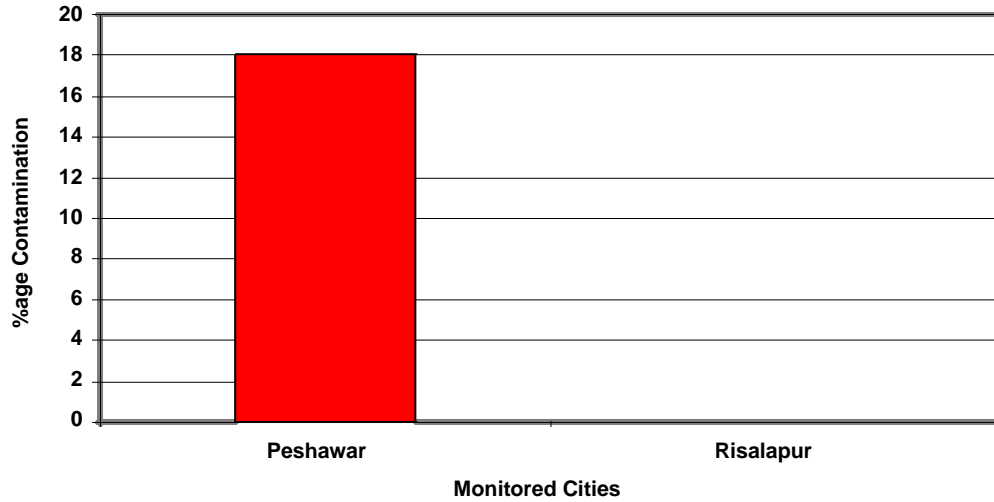


Figure 7. Percentage contamination in North West Frontier Province (NWFP).

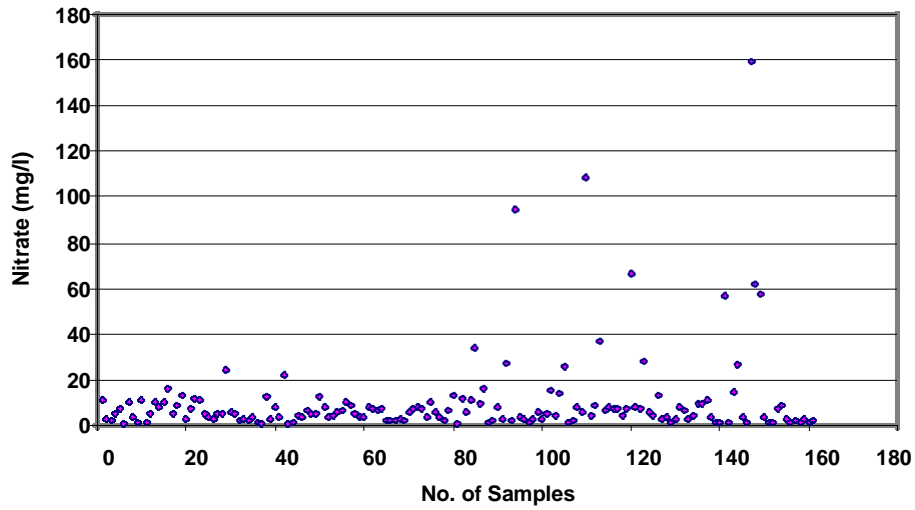


Figure 8. Variation in nitrate concentration (mg/l) in Balochistan province.

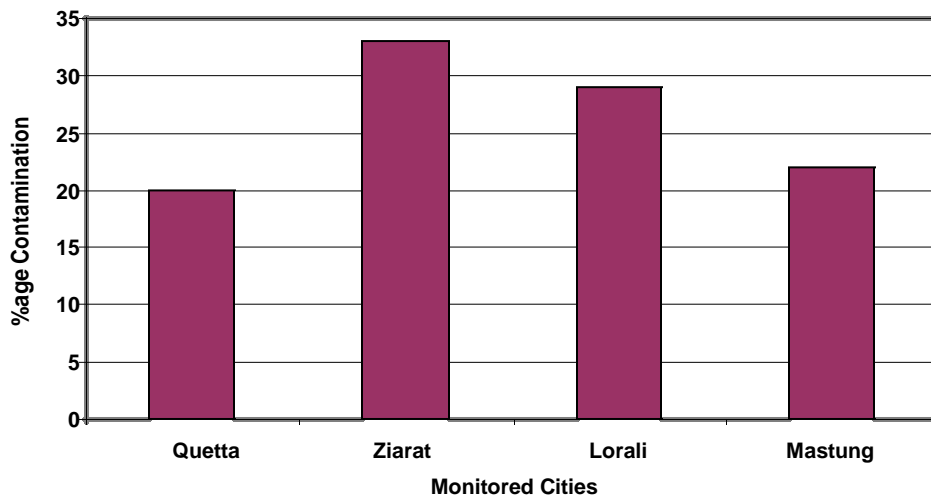


Figure 9. Percentage contamination in Balochistan Province.

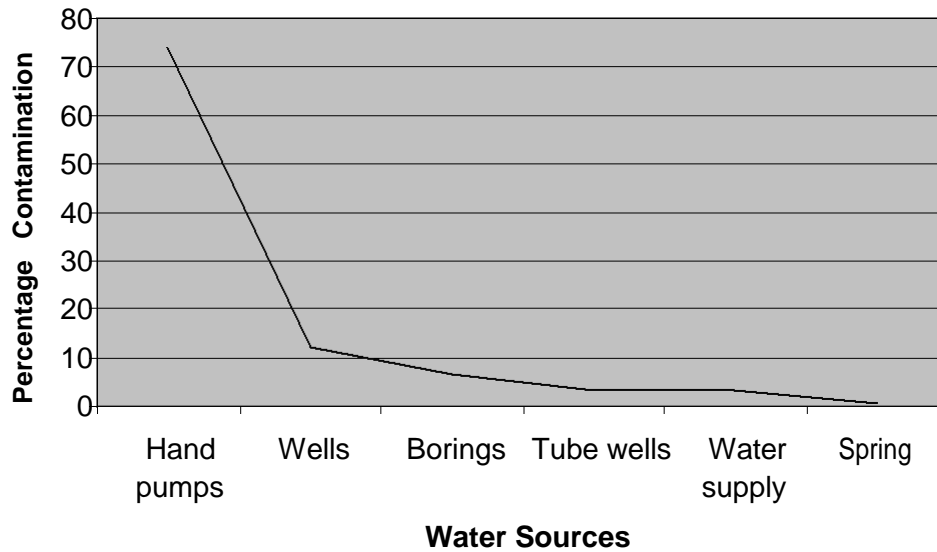


Figure 10. Percentage nitrate contamination in surface and ground water.

Table 1. Provincial crop areas and fertilizer deliveries 2002 – 2003.

Province	Cropped area (million ha)	Percent of total	Fertilizer deliveries ('000 tonnes)	Percent of total
Punjab	16.10	72.8	2 063	68.3
Sindh	3.16	14.4	674	22.4
NWFP	2.01	9.0	204	6.7
Balochistan	0.85	3.8	77	2.6
Total	22.12	100	3 019	100

Nitrogen accounts for 78% of the total nutrients, phosphate for 21% and potash for less than one percent. The average N, P₂O₅, K₂O nutrient ratio between 1999 - 2000 and 2001-2002 was 1:0.28:0.01. Fertilizers imports as a percentage of deliveries for the last five years (1998/99 to 2002/03) averaged about 11% for nitrogen and 72.5 for phosphate.

A heavy dose of nitrogen oxide is also being released in to the environment by industries. Fertilizers, livestock, manures and atmospheric sources are among the top contributors to nitrate contamination of underground water supplies. Analytical findings of Balochistan and Punjab provinces give rise to the prediction that nitrate is more commonly found in the groundwater of rural and agricultural regions of punjab, due to heavy fertilizers use in the cultivated areas and sources like fertilizers application, stagnant ponds, sewage etc may be the multiple reasons of Nitrate contamination in Balochistan. The consumption of fertilizers in Pakistan is determined by geography, weather (water availability), prices and the timely availability of the various products. Punjab has the largest agricultural area and therefore consumes the greatest share of fertilizers, followed by Sindh, NWFP and Balochistan, as shown in Table 1. Trend for the presence

of nitrate in various water sources monitored under this study is graphically presented in Figure 10.

The reason may be that the groundwater in such sources (hand pumps, wells etc.) is drawn from relatively shallow aquifer and shallow groundwater is more susceptible to nitrate contamination particularly in areas with more porous and well drained soils. Concentration of nitrate in the well water depends on the type of soil and bedrock present, and on the depth and construction of the well. It may occur in both shallow and deep well supplies however; generally shallow wells less than 120 feet deep are more susceptible to nitrate contamination, where soils are very porous and where the underlying material is very gravelly. Since, it is very soluble and completely mobile in dissolved form so it can readily move with water through the soil and heavy rainfall or over irrigation moves the nitrate into groundwater systems that may be used for drinking purpose. In general, nitrate concentrations are highest in groundwater near the land surface where nitrogen sources are present (Hallbety et al., 1993). Groundwater that occurs in fractured rocks in mountainous area typically flows in stream. Thus, nitrates that were initially lost through leaching to groundwater can contribute to the pollution of surface wa-

water such as streams, rivers and lakes. Similarly, areas with a shallow water table or sinkholes are more vulnerable to nitrate contamination. Because, they do not evaporate, nitrates are likely to remain in water until consumed by plants or other organisms. Signs and symptoms of medical complexities of excessive nitrate at extensive scale had not been reported in the monitored region however, the problems of hyperthyroidism (goiter) or the insulin dependent diabetes may possibly be prevalent in the affected regions due to excessive nitrate in take through groundwater and it is left to be investigated. In addition to chemical processes, various multiple mechanisms which govern the movement and growth of the nitrate in the prevailing hydro-geological environment include microbial denitrification, volatilization of ammonia and uptake of nitrogen by plants. From the research point of view it is recommended that an insight into the depth specific physical, chemical and biogeochemical processes will be useful in developing a long term projection for the groundwater quality of the study areas and in evolving appropriate surveillance strategies to check nitrate permeation into the aquifers. The World Health Organization cited numerous cases of nitrite intoxication following ingestion of well water containing high levels of nitrate, almost 98% of which were associated with nitrate levels in the range of 44 - 88 ppm (WHO, 1985).

This study has led to the realization that advocacy efforts for the awareness and education of the communities regarding the water quality testing for nitrate contamination, health hazards and ways to prevent drinking water contamination as well as detailed monitoring and mitigation activities are highly recommended for affected areas to safeguard the natives from the possible potential nitrate toxicities.

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