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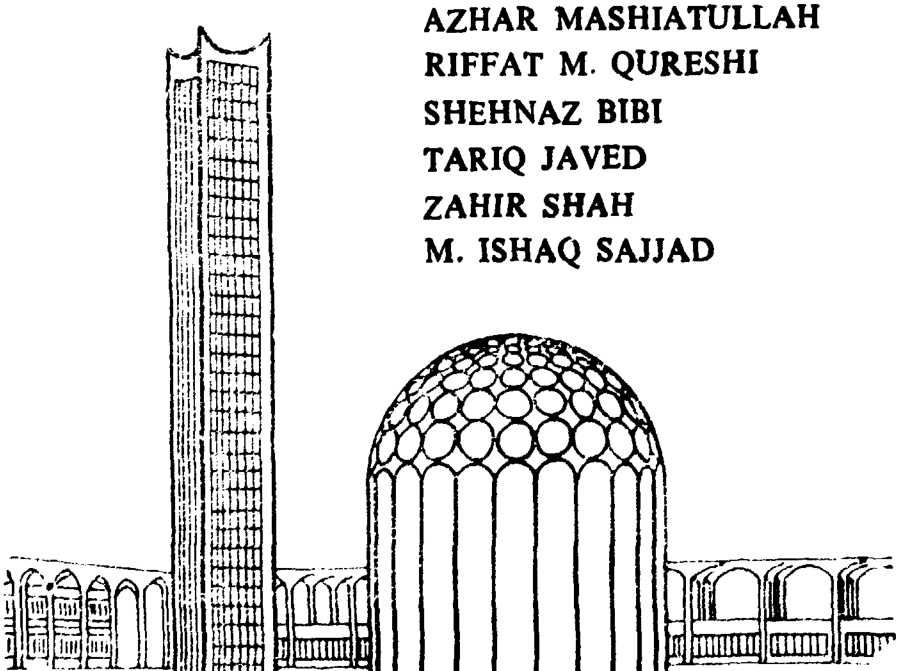

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CONTENTS

ABSTRACT

The coliform group of bacteria are consider to be one of the prominant indicators of surface/groundwater pollution as their presence in drinking water sources shows that water has been in contact with soil, plants, septic tanks or sewerage lines/drains. As a part of surface/groundwater pollution studies in various areas of Rawalpindi city coliform bacteria have been determined in the available drinking water sources (dug wells, tube-wells) to evaluate their possible connection with the nearby septic tanks and sewerage lines/drains.

Representative water samples (10-100 ml each) were tapped from 72 domestic dug wells (shallow groundwater), and 98 municipal corporation tube-wells (deep groundwater) and associated water supply lines in some poorly drained areas of Rawalpindi such as Committee chowk, Dhok Ali Akbar/ Shakarial, Angat pura, Alnoor Colony, Chungi # 22, Dhamial, Jhanda Chichi. These Samples were analyzed using membrane filter technique.

In general, the sampled areas have indicated poor water quality w.r.t. coliform activity. 52% of the collected samples have indicated presence of Ecoli. Of these, 73% samples (38% of the total samples) mostly collected from the poorly drained areas specifically Alnoor Colony, Angat pura (Saidpur road) and Chungi # 22 have shown significant counts of Ecoli (acceptable limits are 10 Ecoli/100 ml). These water are rendered unfit for drinking purposes. Thirteen water samples collected from Committee Chowk area (Chachi Mohallah and Murree Road) indicated toxic levels of Ecoli in the municipal water supply caused due to a known leakage in the main domestic water supply line. After repair one point on the sub-line supply still indicated uncountable Ecoli. The presence of coliform in the tube-well water supply taps are thus attributed to ruptures in the underground water supply lines. Present study reveals that general sanitary conditions and water quality in the city are poor and that there is an urgent need of improvement in the water treatment & distribution systems by the concern quaters

Key words: Biological water quality, water pollution,pollution indicators, drinking water quality, sewerage, waste water disposal.

1. INTRODUCTION

Organisms pathogenic to human that are transmitted by water include bacteria, virus and protozoa. To check drinking water for each of these agents would be a difficult and time consuming job. It is usually not practical to examine drinking water directly for various pathogenic organisms that might be present. In practice indicator organisms are used (1).

Untreated surface water may contain many types of bacteria out of which coliform bacteria is of significant importance. Fecal coliform are useful indicator of sewerage pollution. They provide an excellent mean of monitoring natural water for sewerage pollution because they can be readily detected even in relatively small number using simple microbiological techniques such as membrane filtration (2). Their presence in drinking water would thus indicate that other pathogenic bacteria also exist in association with coliform and that drinking water has been in contact with soil, plants or has been polluted by input from sewerage drains / septic tanks (3).

Coliform group of bacteria include all the aerobic and facultative anaerobic gram negative, non-spore forming rod shaped bacteria which ferment lactose at $37^{o}C$ within 24 hours. In natural environments their best growth temperatures are between 35 - $44^{o}C$. Coliform group consists of fecal and non fecal bacteria. Fecal coliform are predominantly organisms that are found in intestinal tract of man and other animals (1). Non fecal bacteria are not associated with intestinal tract, these are generally found in soil. Some members of fecal coliform group are pathogenic in nature. Coliform is important not only in connection with water pollution but medically also, as a cause of several common form of human infections. Although it lives quite harmless in human intestine, it is one of the bacteria which most commonly causes inflammation in urinary tract and gall bladder. It also causes urinary tract infections in adults specifically, elder people or those whose resistance has been lowered by surgical treatment. It is also abundant in infected tissues of many appendicitis and peritonitis. Certain strains of coliform have been associated with outbreaks of infantile diarrhea(4).

Drinking water properly treated or obtained from a relatively clean source may become contaminated in the water distribution system specially when water supply operates on intermittent basis (5). When water supply is turned off, contaminants from outside can sweep into leaky underground pipes and are carried through the distribution system when supply is turned on again. Poor sanitary conditions in under-developed areas also lead to sewerage mixing with drinking water sources. In many residential areas, septic tanks are located inside the houses close to the underground water storage tanks or dug wells. Improper management of source can also leads to mixing of both waters. Even a small amount of sewerage pollution leads to a large amount of pathogenic organisms in drinking water.

There are two standard methods for the detection of coliform bacteria. First one is the "Most Probable Number (MPN) Technique" which is performed in three phases namely: presumptive, confirmed and complete tests. In the presumptive test a sample of water and dilutions from it are inoculated into the tubes of lactose broth media and tubes are incubated for 24-48 hours. If gas is produced, the test is considered to be positive. For the confirmative test, samples from positive tubes are streaked on to the plates containing special agar media and the plates are incubated for 24-48 hours. Presence of typical colonies indicate coliform. For the complete test, a typical colony is picked and inoculated in the lactose broth. If gas is produced, other biochemical tests are performed. MPN test takes at least 96 hours and these can only be done in the laboratory. The second method of coliform detection is the "Membrane Filter (MF) Technique". In this procedure, a measured volume of water is filtered through a membrane filter (<0.5 micron). The bacteria present in the sample will be retained on the filter. The filter is then placed upon a pad saturated with suitable nutrient medium and incubated at a appropriate temperature. The bacteria which are able to grow on media will produce visible colonies which can be counted. Membrane filter technique requires less incubating space and has an advantage of securing results in considerably less time. This technique is being used on routine basis by many laboratories. With proper care as to the size of sample , medium preparation , temperature & time of incubation and colony identification, the membrane filter technique is an excellent bacteriological tool capable of yielding a more precise and rapid answer than available from other procedures (6).

As a part of surface/ groundwater water pollution studies in Rawalpindi, coliform have been determined in various drinking water sources of the city to evaluate their possible connection with nearby septic tanks and sewerage lines / drains and to determine the impact of pipe-line rupture in the public water supply pipe-line on the quality of drinking water. This paper presents details of these investigations.

2. PRESENT INVESTIGATIONS

Rawalpindi city encompasses an area of about 90 km^2. Its population is nearly one million. The available drainage in Rawalpindi has been interrupted by the unplanned and poor construction in the city and its suburbs. Because of insufficient means of drainage, specifically in poorly developed areas and Kachhi-Abadies like Dhamial. Tench Bhata, Sadiq Abad, Muslim Town, Dhok Khabah, Shakarial, Pindora, Gwalmandi, Jhanda Chichi and Dhok Chragh-Din etc. in Rawalpindi, the waste water gets stored in irregular ponds or accummulates in low-lying streets specially in the rainy season. A major part of this water seeps down and is polluting the soil and shallow subsoil environments. In addition to this, the in-adequate and poor quality sewerage drains as well as drinking water supply lines also leak at many places in these areas and the water in the nearby dug wells (which are the only source of water supply in many Kachhi-Abadies) and domestic supply lines are being contaminated.

A small scale pollution survey in the Rawalpindi city has indicated that most of the inhabitants residing in the polluted areas of Rawalpindi and consuming polluted water are having severe gastric problems, headaches, kidney problems and skin problems etc. Most of these diseases are water born, particularly gastroenteritis which is caused by bacteria, virus, and protozoa(7). These microorgisms mainly enter in the water through sewerage pollution. Even a small amount of sewerage pollution leads to large amount of pathogenic organisms in drinking water. Coliform bacteria was thus selected to investigate water pollution because these are useful indicator of sewerage pollution and can easily be detected using simple techniques.

3. SAMPLING AREA AND FIELD METHODS

In the present investigations, some poorly drained and fairly populated areas such as Dhok Ali Akbar, Alnoor Colony, Angat Pura/ Saidpur Road, Jhanda Chichi, Committee Chowk, Chungi # 22 and Dhamial were selected for water sampling. Figure-1 shows the location of these sampling areas.

About 15 - 30 water samples were collected at random from domestic dug wells, municipal/ cantonment tube-wells and associated domestic water supply taps in the sampling areas. In total 170 water samples were collected from 72 dug wells and 98 tube-wells/associated domestic water supply taps. All samples (250 ml each) were collected in sterilized plastic bottles without any filtration.

To see the feasibility of total coliform as an indicator of known rupture in the under-ground water supply pipeline near Committee Chowk, 13 water samples were collected from associated domestic water taps situated beyond the ruptured pipeline. For cross check after the repair of ruptured pipeline, samples were collected again from the same houses and analyzed for total coliform counts.

4. LABORATORY METHODS

4.1. Materials

Autoclavable plastic bottles (50 - 100 ml), pyrex glassware (1l volumetric flask & 500 ml beaker), autoclave, dry sterilizer (oven _ 160 - 300°C), chemical sterilizer (methanol RG), spatula, stainless steel forceps, aluminium petri dishes, magnifying glass, sterilized membrane filters (47mm, GN6 grid, 0.45μm, M/S Gelman Sciences Inc. Michigan 48106. USA), absorbing pad, dropper, top loading balance (accuracy $\pm$ 0.01gm, hot plate, Paqualab incubator & filtration system (M/S ELE International Ltd., Eastman Way, Hemel Hempstead, Hertfordshire HP2 7HB England), dehydrated membrane Lauryl sulfate H9 for broth preparation (M/S ELE International Ltd. England),

4.2. Experimental Methods

Membrane filter (MF) technique was used to detect fecal & total coliform bacteria in water samples. The bacterial medium (broth) was prepared by dissolving 38.1 grams of dehydrated Lauryl sulfate in 500 ml of distilled water. This media was then dispensed in 50 - 100ml plastic bottles and autoclaved at 121^{0}C for 15 minutes. Aluminium petri dishes with absorbent pad and the forceps were dry *sterilized at 160^{0}C for one hour.* Approximately 10ml of autoclaved media was poured onto the absorbent pad in the petri dishes with the help of a sterilized dropper. The field water sample was drawn through a membrane filter (<0.45μm) with the help of Paqualab filtration unit. The membrane was carefully removed with the forcep and placed onto the absorbent pad in the petri dish. After each sample filtration, the components of the filtration unit and the forceps were chemically sterilized. Petri dishes with membrane filter were then placed in the stack of Paqualab incubator at 37 $\pm$ 0.5^0 C for 16 hours for the determination of total coliform. In case of fecal coliform counts, the temperature was raised to 44 $\pm$ 0.5°C. Yellow colonies with silver sheen of size 1-3 mm were counted with the help of magnifying glass. 15-30 samples were collected from each area at random.

5. RESULTS AND DISCUSSIONS

Figure-2 presents a general scenario of the coliform contamination in sampled drinking water sources. Of the total samples (n=170) analyzed, 52% samples (n=88) were found contaminated with coliform. Of these, 64% samples (n=57, 34% of the total samples) were found unfit for drinking purposes in view of the limits (_10 Ecoli per 100 ml) prescribed by the WHO (8). Figure-3 further elaborates on the distribution of coliform contamination among the dug well water supply and the tube-well water supply. Of the total dug well samples (n=72), 65% samples (n=37) were found contaminated with coliform. Of these, 95% samples (n=35 , 48% of total dug well samples) were found unfit for drinking purposes. Of the total tube-well samples (n=98), 43% samples (n=42) were found contaminated with coliform. Of these, 60% samples (n=29, 30% of total tube-well samples) were found unfit for drinking purposes.

It is noteworthy that permissible levels of coliform were detected in the water supply of those dug wells where people had used potassium permanganate, sodium chloride or lime regularly as bacterial disinfectant. However, in case of tube-well supply, this effect was not so pronounced. Figure-4 presents an over-view of coliform contamination in treated and untreated dug well and tube-well water supply samples. Out of 72 dug well samples, 65 water samples were not treated with any bacterial disinfectant, while 7 samples were treated with either lime, $KMnO_4$ or NaCl. Among the treated dug well water samples, 57% samples (n=4) contained coliform. None of these samples were found unfit for drinking purposes. Among the untreated dug well water samples, 66% samples (n=43) were contaminated with coliform. Of these, 82% samples (n=35) were found unsuitable for drinking purposes. Out of 98 tube-well water samples, 76 water samples were not treated with any bacterial disinfectant, while 22 samples were treated with chlorine gas at the source by the M.E.S. authorities in the "Chungi No. 22" area. Among the treated tube-well water samples, 32% samples (n=7) contained coliform. Of these, 85% samples (n=6) were found unfit for drinking purposes. Among the untreated tube-well water samples, 55% samples (n=42) were contaminated with coliform. Of these, 69% samples (n=29) were found unsuitable for drinking purposes. Although, the percentage of coliform contamination is less in treated tube-well water samples as compared to the untreated tube-well water samples, their presence in the treated samples could be attributed to either small concentrations of chlorine gas (the gas is consumed as a matter of reaction with the pipeline material) upon travel to sampling points quite distant from the source tube-well, or use up of chlorine gas due to input of uncountable coliform through rupture in the underground water supply line.

Figure-5 shows the extent of coliform contamination in drinking water samples collected from the seven study areas. Figure-6 further elaborates on the distribution of coliform contamination among the dug well water supply and the tube-well water supply. Results are summarized for each of the study areas in the following section:

5.1. Dhok Ali Akbar Area:

In this area, 30 drinking water samples were collected from 22 dug wells and 8 tube-well supply connections. Only one tube-well installed recently in this area supplies water to some of the closeby streets. 41% of the dug well water samples (n=9) were found contaminated with coliform. Of these, 66% samples (n=6) were found unfit for drinking purposes. 50% of the tube-well water samples (n=4) contained coliform. Of these, 75% water samples (n=3) were found unsuitable for drinking purposes. The streets in this area are mostly un-cemented and contain open drains. The septic tanks are also poorly designed. The tube-well management in this area does not use any treatment method to purify water. The observed contamination in dug wells is attributed to a possible connection of septic tanks and open sewerage drains with the domestic dug wells in this area. The observed contamination in tube-well water supply is attributed to the input of sewerage water into the domestic pipeline connection through loose joints as these are dipped in the sewerage drain and/or soil alongside the street wall on their way from the main municipal supply line pipe.

5.2. Alnoor Colony Area:

In this area, 21 drinking water samples were collected from dug wells. Although, a tube-well has been installed in this area for public water supply, it was not operational at the time of sampling. 95% of the dug well water samples (n=20) were found contaminated with coliform. All of these samples were found unfit for drinking purposes. This area is very poorly developed. Waste deposits are quite common along street corners and in open plots. Animal farms also add up to this waste. The streets are mostly un-cemented and have open drains and pits. The in-house septic tanks are also poorly designed. The observed contamination in dug wells is therefore attributed to a possible connection of septic tanks and open sewerage drains with the domestic dug wells in this area.

5.3. Angat Pura Area:

In this area, 22 drinking water samples were collected from 5 dug wells located in very old houses and 17 tube-well supply connections. Due to frequent supply of tube-well water by the municipal corporation, most of the domestic dug wells have been closed. 100% of the dug well water samples (n=5) were found contaminated with coliform. Of these, 60% samples (n=3) were found unfit for drinking purposes. 49% of the tube-well water samples (n=8) contained coliform. Of these, 63% water samples (n=5) were found unsuitable for drinking purposes. The streets and associated drains in this area are mostly cemented but the drainage is very poor. The level of old houses is about 1 foot lower than the street level. The septic tanks are also poorly designed. At many places, the domestic connection pipes of municipal water supply dip into the sewerage drains alongside the street wall and/or buried in soil. The tube-well management in this area does not use any treatment method to purify water. The observed contamination in dug wells is attributed to a possible connection of septic tanks with the domestic dug wells in this area. The observed contamination in tube-well water supply is attributed to the input of sewerage water into the domestic pipeline connection through loose joints as these are dipped in the sewerage drain and/or soil alongside the street wall on their way from the main municipal supply line pipe.

5.4. Jhanda Chichi Area:

In this area, 36 drinking water samples were collected from 4 dug wells and 32 tube-wells. Very few dug wells exist in this area due to the installation of public water supply tube-wells by the cantonment. 50% of the dug well water samples (n=2) were found contaminated with coliform. Of these, 100% samples (n=2) were found unfit for drinking purposes. 53% of the tube-well water samples (n=17) contained coliform. Of these, 53% water samples (n=9) were found unsuitable for drinking purposes. The streets in this area are mostly narrow cemented but contain open drains. The drains are also broken at various points. At many places, the domestic connection pipes of cantonment water supply dip into the sewerage drains alongside the street wall and/or buried in soil. The septic tanks are also poorly designed. The tube-well management in this area does not use any treatment method to purify water. The observed contamination in dug wells is attributed to a possible connection of septic tanks and open sewerage drains with the domestic dug wells in this area. The observed contamination in tube-well water supply is thus attributed to the input of sewerage water into the domestic pipeline connection through loose joints at the time of forced suction by electric pumps.

5.5. Dhamial Camp Area:

In this area, 25 drinking water samples were collected from 20 dug wells and 5 tube-well supply connections. Only one nearby union council tube-well supplies water to some of the houses located in this area. 55% of the dug well water samples (n=11) were found contaminated with coliform. Of these, 36% samples (n=4) were found unfit for drinking purposes. None of the tube-well water samples (n=5) contained coliform. In the Dhamial area(Quaid-i-Azam colony) where tube well samples were collected, the streets are mostly cemented and adequate underground sewerage facilities also exist. However, in the area of dug well samples, the streets are un-cemented but the sewerage drains are adequately placed underground. Nevertheless, the septic tanks are poorly designed. The tube-well management in this area does not use any treatment method to purify water. The observed contamination in dug wells is attributed to a possible connection of septic tanks with the domestic dug wells in this area.

5.6. Chungi No. 22 Area:

In this area, 23 drinking water samples were collected from M.E.S. tube-well supply connections. The dug wells in this area have been closed due to the frequent supply of tube-well water by the M.E.S. 30% of the tube-well water samples (n=7) contained coliform. Of these, 87% water samples (n=6) were found unsuitable for drinking purposes. The M.E.S. authorities use chlorine gas for water purification. The streets in this area are cemented but contain open drains. At some places, the domestic connection pipes of M.E.S. water supply dip into the open sewerage drains alongside the street wall and/or burried in soil. The septic tanks are also poorly designed. The observed contamination in tube-well water supply is thus attributed to the input of sewerage water into the domestic pipeline connection through loose joints at the time of forced suction by electric pumps installed in the houses.

5.7. Committee Chowk Area:

In this area, 13 drinking water samples were collected from the municipal tube-well supply domestic connections in Chachi Mohallah and Murree Road in the Committee Chowk area. The previously available dug wells in this area were closed after the installation of public water supply tube-wells by the municipal corporation. 46% of the tube-well water samples (n=6) contained coliform. All of these water samples were found unsuitable for drinking purposes. The streets in this area are mostly cemented and contain open sewerage drains. The domestic connection pipes of water supply are burried in soil. The septic tanks are also poorly designed and their leakage may add up coliform in the nearby soil in the street. The observed contamination in tube-well water supply is thus attributed to the input of this coliform activity to the domestic pipeline connections through loose joints at the time of forced suction by electric pumps and also due to the rupture in the underground main water supply line.

Water samples collected in triplicate from the same locations after appearance of a rupture in the water supply pipeline indicated toxic levels of Ecoli. After repair of the pipeline, one point on the sub-line supply still indicated uncountable Ecoli. The presence of coliform in the tube-well water supply taps are thus attributed to ruptures in the underground water supply lines.

Present study Concludes that the general sanitary conditions and water quality in Rawalpindi city are poor. There is an urgent need of improvement in the water treatment & distribution systems. In many industrialized countries, many type of waterborne diseases have been effectively controlled through the general introduction of innovative method of water treatment & distribution and improved means of sewerage collection, treatment and disposal (3).

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Fig. 1: Location of water sampling areas in Rawalpindi City.

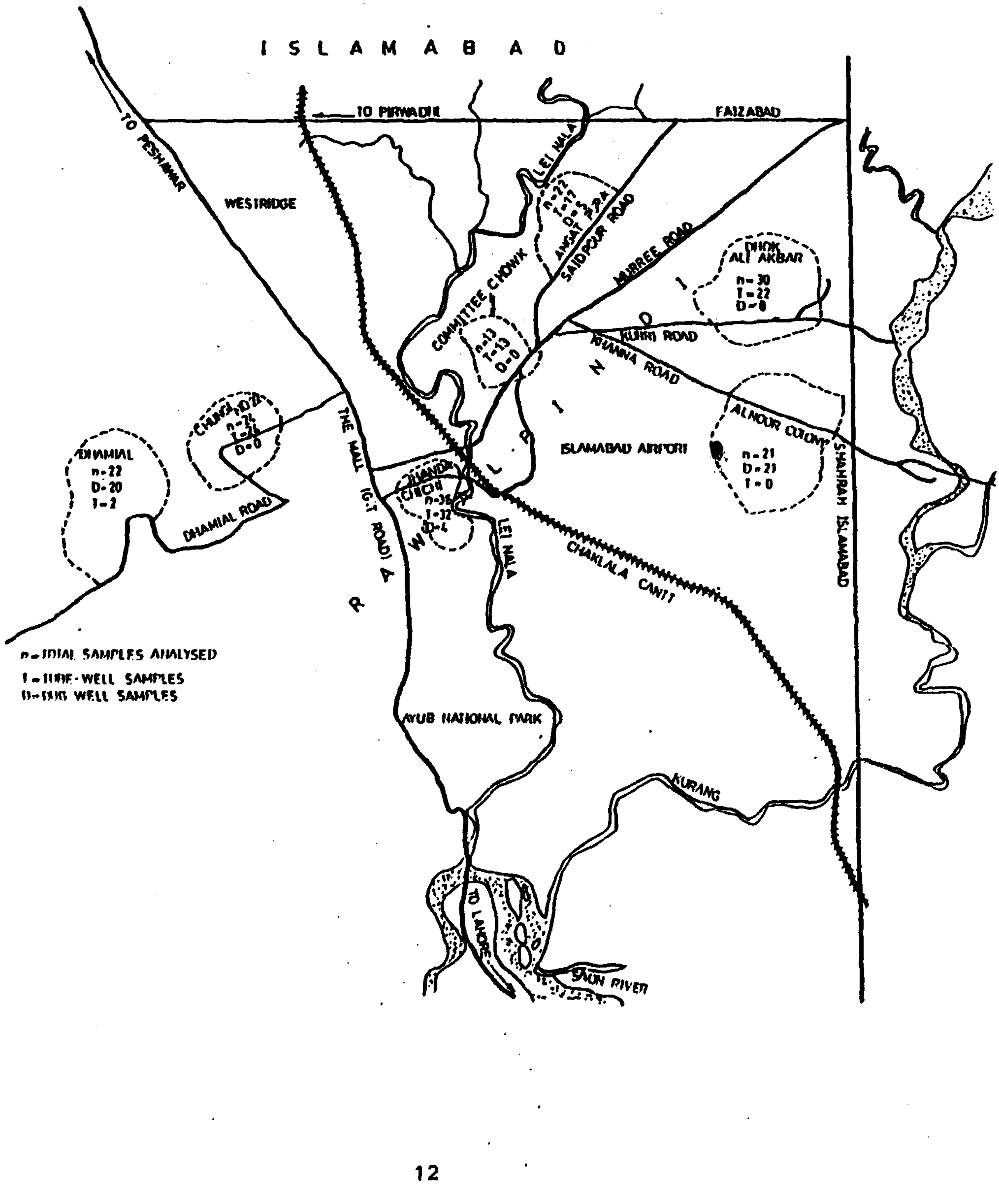

Fig-2: Coliform contamination scenario of domestic water supply in Rawalpindi

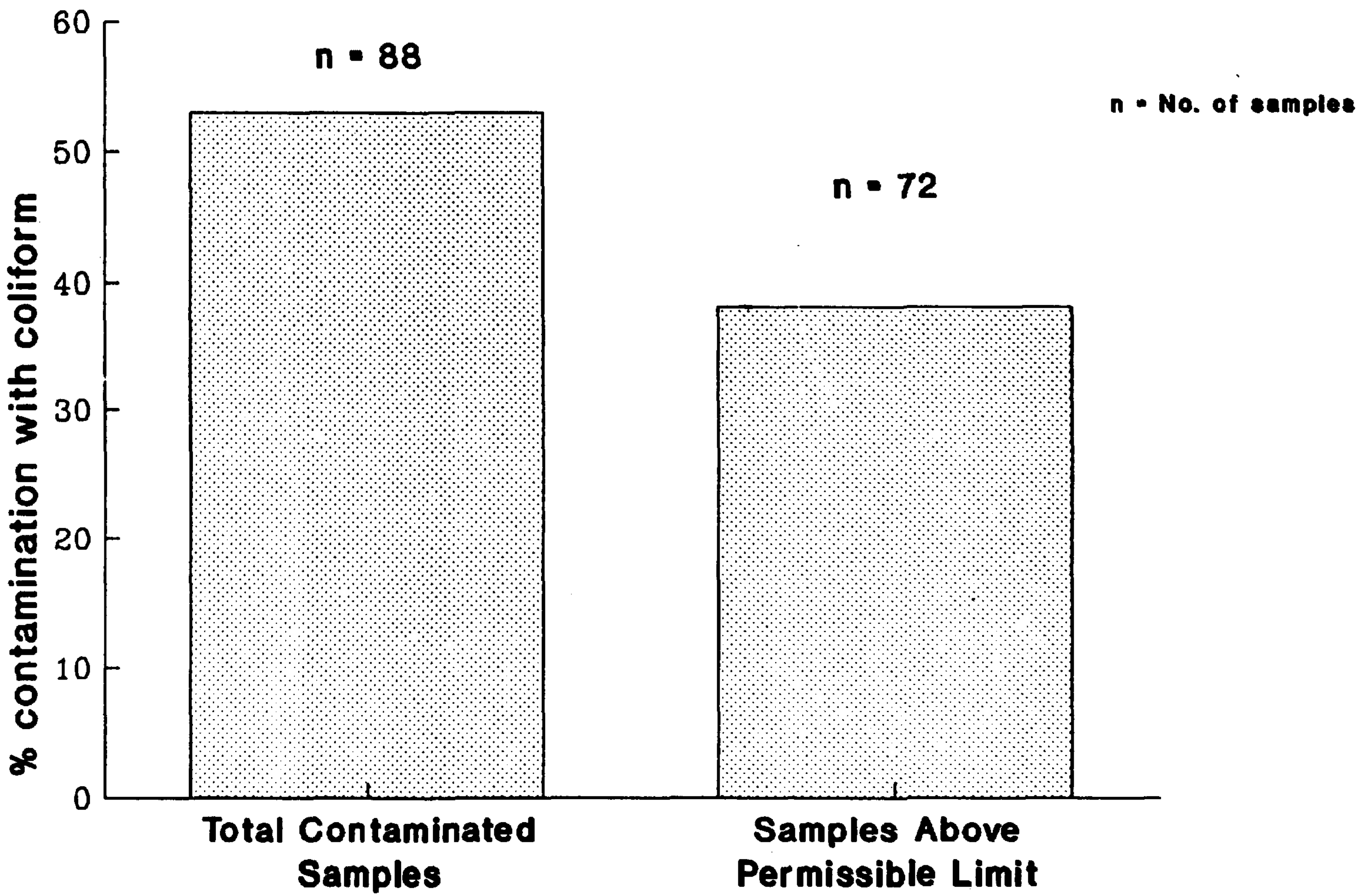

Fig-3: Coliform contamination in dug wells & tube-wells (Rawalpindi city)

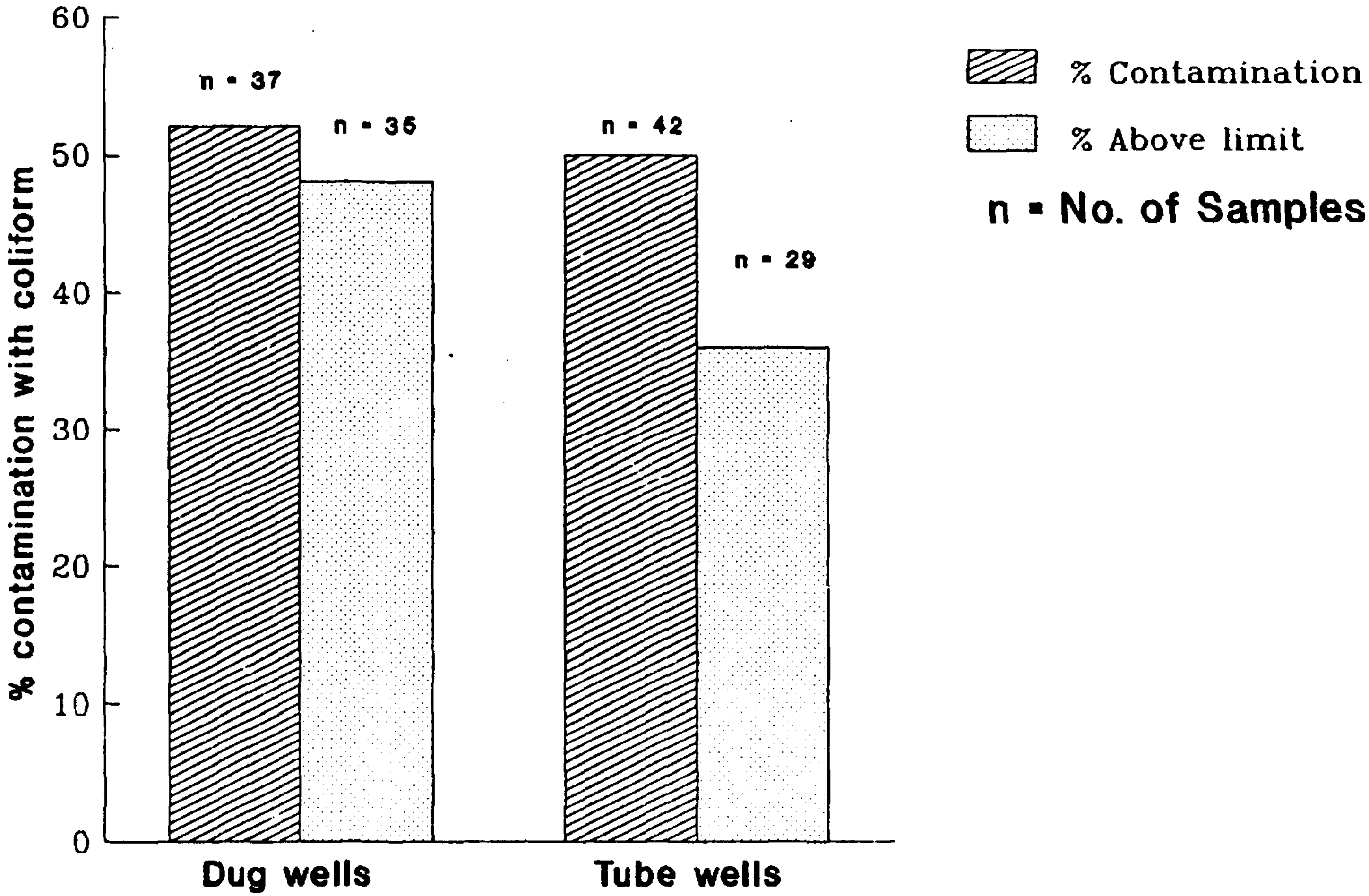

Fig-4: Coliform contamination in treated and untreated water supply

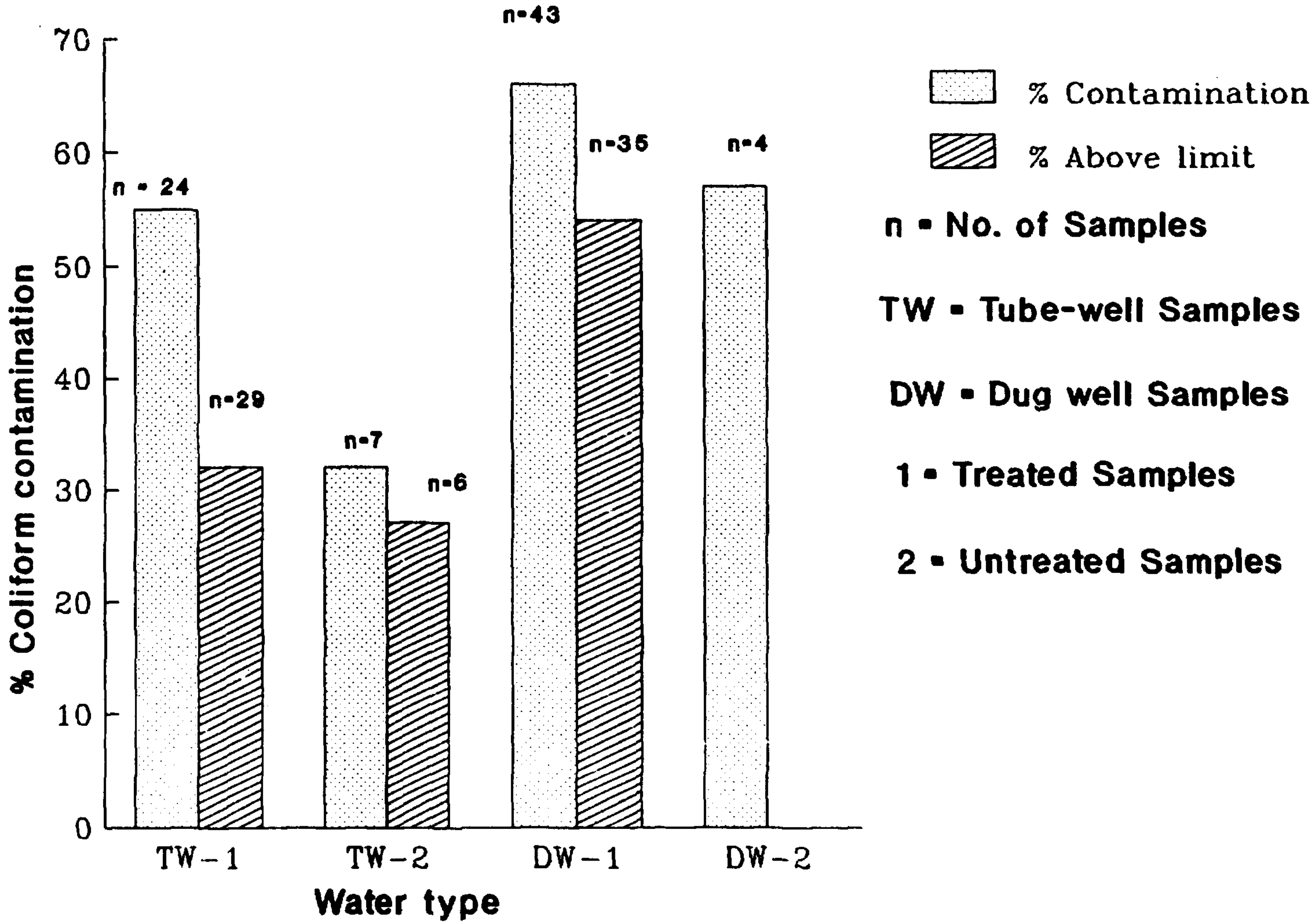

Fig-5: Extent of coliform contamination in drinking water supply of study areas

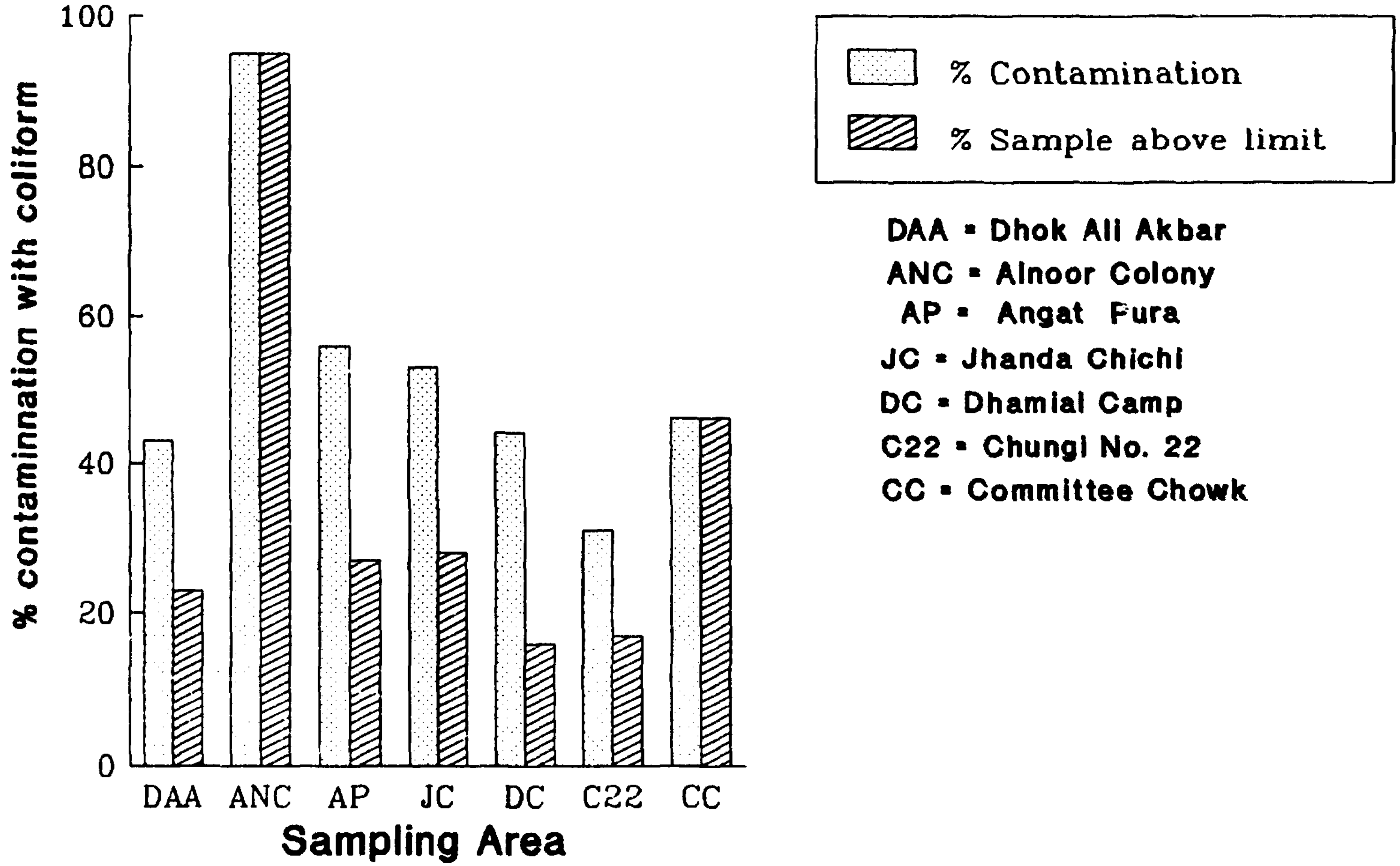

Fig- 6: Coliform contamination among dug well and tube-well water supply