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BIOLOGICAL STUDIES ON SOME GHANATS
OF IRAN

by

Fardin Oliaei

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Biology

Western Michigan University
Kalamazoo, Michigan
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Fardin Oliaei

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CHAPTER I

INTRODUCTION

Statistical surveys dealing with water requirements on a world-wide basis have shown that demands for water for human consumption, agriculture, and industry are increasing at a dramatic rate. It is anticipated that the demand for water will eventually outpace available resources.

In Iran the amount of available water is limited, its quantity depending on seasonal fluctuations in rainfall. There are many areas which face problems of diminishing water supply. Because of the increasing water demand, concomitant with the growth in population and industry, it is estimated that water demand in Iran will exceed available natural supplies by the turn of the century. This predicted shortage of water constitutes a challenge that can only be met by careful planning and intensified research to achieve maximum utilization and reuse of water.

In the capital city of Tehran, water is supplied by two nearby rivers: the Karadj and the Judjrood. At present, during peak demand, the water supply is increased by drawing water from underground strata. A unique system, which is the most common means of exploiting underground water in Iran, is the ghanat.

These ghanats presently are the primary source of potable water for many of the city inhabitants. However, they are used not only for drinking water, but as sites for the washing of clothes and dishes, and often as bathing pools.

The purpose of the present study is to determine the extent and type of contamination present in ghanats of Tehran. Algae surveys and bacterial analyses were undertaken to evaluate contamination. The present research aims at studying the seasonal occurrence (winter, summer) and distribution of bacteria and algae in ghanat systems and determining if they have any relationship with various physicochemical and algological parameters in water quality.

The Ghanats of Iran

Most of Iran, except for a few limited areas in the northwestern provinces and along the southern shores of the Caspian Sea, receives as little as 6 to 10 inches of rainfall annually. Despite this low rainfall, Iran is essentially a farming country, producing crops for export. These crops include cotton, dried fruits, oil seeds, and others. This agricultural activity is made possible because of the unique system for utilizing water which is present in underground filtration tunnels or "horizontal wells," variously known as ghanat, kareis, or foggaras.

Ghanats are found throughout the Middle East, and are particularly abundant in Iran. Essentially, the ghanat is

a gently sloping tunnel, usually along the radius of an alluvial fan. This fan extends up-slope until the water table is tapped; it emerges at the down-slope end to supply an oasis.

Rain, which falls on the highlands, quickly runs off the bedrock of the mountains and seeps into the gravels and sands of the bordering fans. Water moves underground from the margins of the basins, with most of the runoff going underground within a few miles.

Many of the ghanats of Iran, which are still in use, were constructed at least 3,000 years ago; there are approximately 22,000 of them in Iran, comprising more than 270,000 km of underground channels, and supplying 75% of all water used in the country.

Present methods of constructing a ghanat differ little from those of thousands of years ago. Typically the system is dug in the slope of the mountain or hillside where material washed down the slope has been deposited in alluvial fans. Upon locating a promising spot, a trial well is dug. Special diggers, mughanni, undertake this task. Excavated materials are piled around the mouth of the shaft, and when a moist stratum is reached, the diggers scoop out a cavity in its impermeable clay bottom. If the water flow is sufficient, it is concluded that an aquifer has been tapped. More shafts may then be sunk to determine the extent and yield of the aquifer.

The surveyor next charts the possible course of an underground conduit through which the water can flow from this head well, or group of wells, to the ground surface at a point somewhat farther down the slope. He selects a gradient somewhere between 30 cm in 1,500 and 30 in 4,500. The gradient must be such that the water will flow slowly, and not wash material from the bottom of the conduit or otherwise damage it. Vertical shafts for ventilation are sunk at measured intervals (about 45 m) along the path of the conduit. Excavation of the conduit is started from the mouth end, digging into the alluvial fan. The conduit is about 1 m wide and 1.5 m high. Ghanats vary greatly in length, depending on the depth of the aquifer and the slope of the ground. Commonly, the length is between 10 and 80 km, but may be as much as 30 m or as little as 9.

Figure 1 shows the longitudinal section of a ghanat system, which is divided into six parts. The parts, with the Iranian terminology in parentheses, are as follows: (1) open part of the conveyance canal (haranj); (2) outlet, or the point of emergence of water (mazhar); (3) dry part of the conveyance tunnel (khoshkeh kar); (4) wet part of the draining tunnel (tar kar); (5) vertical shafts for aeration or access (mileh); and (6) uppermost shaft, or mother well (madar chah). An underground aqueduct conveys water gently downhill from the highlands to distribution canals in the arid plain below by force of gravity.

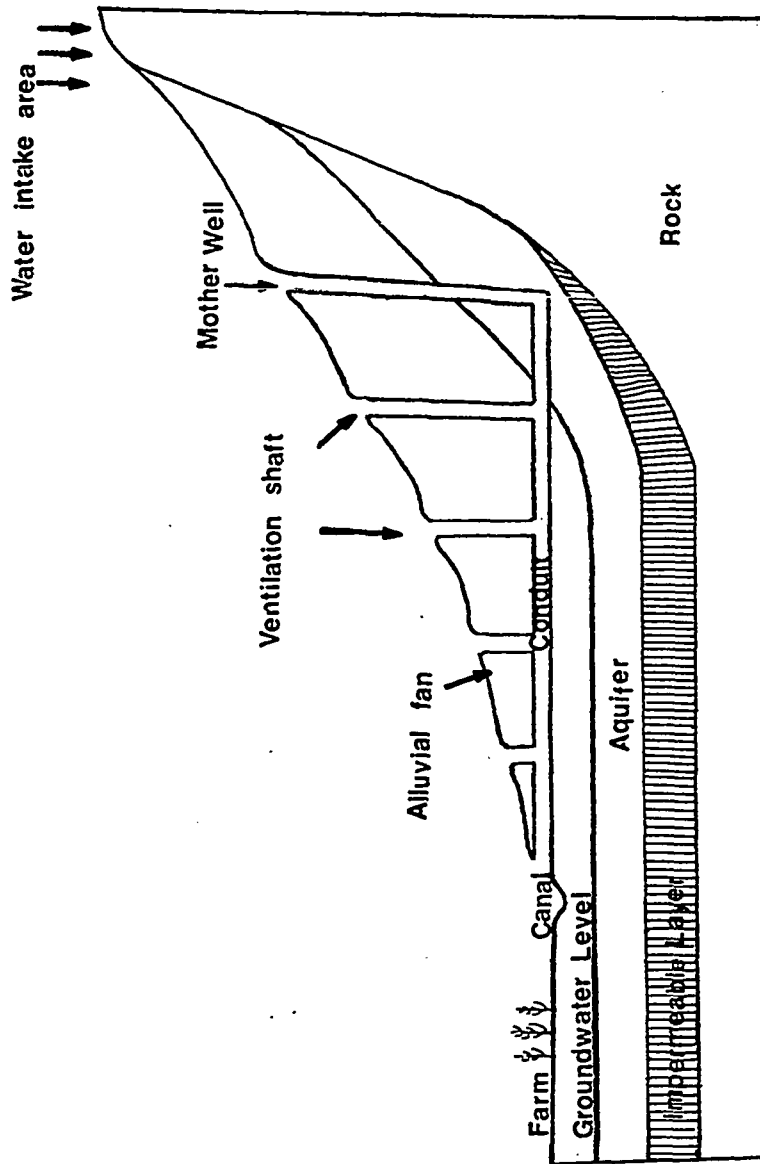


FIGURE 1. LONGITUDINAL SECTION OF GHANAT

Both the building of the ghanats and the distribution of the water are directed by laws and common understandings that are based on tradition. There are also traditional systems for the fair allocation of water from a ghanat to its users.

The yield of the ghanats varies according to ground-water characteristics, the porosity of the soil, and the season. Some have a nearly constant flow throughout the year; others function sporadically. In many towns the ghanats terminate in the bazaar or in a mosque or in the home of the owner. Some houses have a summer living room through which a ghanat passes.

In many parts of Iran, particularly in the central plateau, a great number of villages and farms obtain their domestic and irrigation water requirements from ghanats.

Since ghanats are the key to life in these arid regions, it is necessary to reverse the effects of pollution or to maintain natural waters in a healthy state.

CHAPTER II

REVIEW OF SELECTED LITERATURE

Microbiological Contamination

The possibility that enteric diseases may be waterborne, both in endemic form and in the form of sporadic cases, calls for the development of methods for evaluating the safety of water supplies from a bacteriological point of view. Information gained from these studies would enable one to determine which materials disturb the ecology of natural waters, and which would be potentially hazardous to man.

In order to assess the degree and seriousness of pollution, it is not essential to isolate and identify all the organisms in the water which possibly are the etiologic agents of a particular disease. This flora, even in water from deep in the ground, is relatively constant in quality. The ability of natural waters to rid themselves of microbial contamination is a function of the diverse native microflora of the natural ecosystem (Mitchell, 1972). The increase of this flora in numbers, therefore, may indicate an influx of foreign bacteria, especially when these variations coincide with periods of heavy rains or snow-melt, conditions which favor such contamination.

It is important, however, to search for microbiological indicators of pollution. The main studies to be conducted

in considering the variation in the water's total bacterial population are (a) studies of pathogenic bacteria and (b) studies of bacteria of fecal origin.

Laboratory investigations usually consist of examinations for bacterial pathogens, including Entrobacter, Klebsiella, Serratia, and Citrobacter as total coliforms, and Klebsiella and Escherichia as fecal coliforms, and a means of total count for bacteria.

Practically all the pathogenic bacteria which enter through the digestive tract are of fecal origin (Geldreich, 1966). Therefore, it might be assumed that water may contain pathogenic organisms whenever the presence of fecal matter in water has been established. The enumeration of indicator organisms, including total coliforms and fecal coliforms, in any fresh-water system is an accepted method of determining possible contamination from human sanitary waste facilities. The reduction in the quality of the water, so far as pathogens are concerned, is evident (Water Pollution Control Federation Journal [WPCF], 1978).

The term "coliform" refers to "all of the aerobic and facultative anaerobic Gram-negative, non-spore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C" (Standard Methods, 1965). The use of membrane filter technique has led to the establishment of another definition of coliforms which is described in Standard Methods as follows: "all organisms which produce a dark

colony with a metallic sheen within 24 hours of incubation (on a specified medium and at specified temperature)." Cooke et al. (WPCF, 1978) reported that the New Zealand Microbiological Society Committee have recommended the use of coliform bacteria as indicators of pollution until such time as more specific organisms are identified and internationally recognized.

Anjaneyulu (WPCF, 1978) reported a positive correlation between the number of coliforms present and fecal streptococci. He suggested that the number of fecal streptococci present should supplement the coliform number as a presumptive indicator of pollution for ground water. Mirazoev (WPCF, 1978) stated that because Escherichia coli, as a coliform, is ubiquitous, its presence did not necessarily indicate fecal contamination. He based this statement on the fact that E.coli comprises only 2% to 3% of the total fecal microflora.

Hass (WPCF, 1978) agreed that the current use of coliforms as indicators of pollution, or as an indication of treatment efficiency, fails to safeguard totally against all pathogenic organisms which could be present. Furthermore, as McCobe (WPCF, 1978) suggested, indicators may be useful in developing water sources, but appear to be of limited value for monitoring waterborne diseases. De Malignon (WPCF, 1978) stated that monitoring of drinking water distribution systems must be made intensive, including tests for pathogens.

In a review of bacterial indications of water pollution, Bonde (WPCF, 1978) stated that a bacterial indicator of pollution is inexpensive, rapid, and a very useful tool that cannot be replaced by chemical tests or by demonstration of pathogens. Though many authors stress the advantage of one method over another, under certain conditions different results may be obtained. Possibly the water could contain toxic substances responsible for the prevention of the development of bacteria. In such a case, filtration, which isolates the bacteria from their natural environment, is helpful to the investigator.

While total coliforms are an important measure of sanitary quality of treated drinking water, and fecal coli are a prime indicator of pathogenic water quality investigations, more effort should be made to apply a wide range of indicators to resolve specific concerns. The feasibility of utilizing both yeasts and molds as indicators of efficacy of disinfection was evaluated by Engelbrechet et al. (WPCF, 1978). Geoffary and Vial (WPCF, 1978) mentioned that membrane filtration (MF) is especially suitable for clear water with a low bacterial contamination. Pipes et al. (1977) presented evidence to support the hypothesis of the MF coliform count.

Borner et al. (WPCF, 1978), reporting in a symposium, have emphasized the problems which occur with the recovery of bacterial indicators from waste water and drinking water by membrane filter. These include such factors as media

quality, transport phenomena, physical and chemical characteristics of membrane, membrane sterilization methods, incubator temperatures, techniques for comparison of methods, data analysis, and the recovery of organisms pressured or injured by environmental factors.

The quality of the raw water determines whether it may be distributed as such or if treatment is necessary in view of sanitary regulations or, finally, whether treatment is possible. The French regulations of 1961 require that such water may not contain any E.coli in 100 ml, any fecal streptococci in 50 ml, or any sulfite-reducing Clostridia in 20 ml. Water thus is nonpotable when fecal pollution has been proven. The present tendency of hygienists, in accordance with the World Health Organization (1971) recommendations, is to impose more stringent criteria for the bacterial quality of water.

Planktonic Algae

It was concluded that microbiological testing alone cannot guarantee the "safety" of the water. The quality of drinking water from a public water supply should be determined by chemical and algological states in addition to the bacteriological examinations (Cairns, 1969). It was reported that changes in structure and type of algal communities may be caused by pollution. Such changes may affect other aquatic organisms and as such may be utilized as criteria

for monitoring water quality. The evidence for such changes is usually based on identification of algal species. Algal species may be identified either by form or function (Cairns et al., 1968; Cairns & Dickson, 1971). The most commonly used criteria for algal identification have been form.

Problems caused by algae are usually due to presence of five different categories. These types are: plankton algae; drinking water algae (primarily cold-water forms); algae tolerant to organic pollution (can be used as pollution index if 50 or more per ml of sample); filter-clogging algae, such as mixed diatoms; and attached algae, a group which includes most of the filamentous forms such as Cladophora, Stigeoclonium, Oedogonium, and Ulothrix. These latter can change the chemical composition of raw water.

Among the planktonic forms which are tolerant of pollution are Stigeoclonium and Chlorella of the Chlorophyta; Oscillatoria and Microcystis of the Cyanophyta; Volvacoids such as Chlamydomonas; and numerous diatoms such as Synedra, Nitzschia, Navicula, Tabellaria, Fragilaria, and Asterionella (Palmer, 1963; Ward's Natural Science, 1971).

The utilization of a listing of species for describing a microbial community is actually a description of the number of different kinds of particles present, for example, an aggregation of particles of a different size and structure in a community of diatoms. It is important to realize that algal communities must be considered, not just a particular

genus or species, when evaluating water quality. Too large a population of any nuisance algae usually also has many other objectionable traits.

Typically the response pattern of a community to all forms of pollutional stress is a reduction in number of species present, with an accompanying increase in the number of individuals per species within the community (Patrick, 1949).

The effect of changes in the physical parameters on the growth and metabolism of algae is under investigation by many workers. In fresh water, the optimum temperature for the great majority of algae lies between 10° and 15°C, and some others lie between 20° and 25°C. Some species will decrease and disappear from the flora as the temperature decreases; others, especially the diatoms, reach a peak of development. Chrysophyta, however, are dominant as a winter plankton, along with Cryptomonas (Prescott, 1970). Penetration of light into bodies of water is related to seasonal changes; thus, the development of many algal species is determined by seasonal recurrences of a suitable amount of light. Goriumcova and Nasonova (Mitchell, 1972) reported a seasonal fluctuation of growth intensity of protococcus algae; this observation, however, was not confirmed by other authors such as Shaposhniko et al., and Vladimirova and Ignatuvskaja (Mitchell, 1972). Light can account for the periodic appearance of algae such as Microcystis, Anabaena, and Oscillatoria.

Planktonic forms such as Chlamydomonas and many other flagellates are capable of heterotrophic growth in the dark (Prescott, 1968).

The effect of organic compounds and their critical role on the structure and function of phytoplankton algal communities have already been evaluated (Bozniak, 1969; Collier, 1973; Wagnersky, 1965).

Cairns (Mitchell, 1972) reported that, under certain circumstances, a small increase in organic loading of the water might lead to an increase in the number of individuals per species and the number of species, also. If the amount of organic material is substantial, a major disequilibrium may result by rapid replacement of existing microbial communities by species different in both structure and function. Algae have microchemical requirements which are related to cellular functions such as respiration, photosynthesis, and nitrogen fixation. Eyster (1958), Lewin (1962), and Krauss (1955) reported Fe, Mg, Zn, Cu, Co, Mo, Ca, Cl, Na, Si, and I as essential microelements.

Research involving various culture techniques and field observations has demonstrated that generally there are increases of nitrogen and phosphorus to cause the growth of certain species and the decline in others (Edmondson, 1959). Some reports indicate that carbon, rather than phosphorus, is the controlling nutrient of algal growth. The Lange-Kuentzel-Kerr hypothesis, for example, indicates the

existence of an extremely efficient mutually supportive relationship between blue-green algae and bacteria. Bacteria degrade organic matter and produce CO₂ which the algae utilize in the photosynthesis of new organic matter. At the same time, the algae liberate oxygen which the bacteria, in turn, utilize in the digestion of organic matter. Nitrogen, phosphorus, and other necessary substances are cycled between the algae and bacteria and the environment during the process (Legg & Dingeldein, 1970).

Under some natural conditions where bacteria are abundant, it is possible that some organic growth substances may be produced which are available to the algae.

Wright and Hobbie (1966) concluded that bacteria were able to control substrate levels (unlike algae) and therefore might prevent heterotrophic algal growth.

One aspect of algal-human relationship is the association between toxic algae and human diseases. In 1836, Valentin first reported the isolation of algae in normal animal alimentary tracts (Jackson, 1967).

The predominant algal groups which have been found in digestive systems have been blue-greens, greens, and diatoms. According to Schwimmer (Jackson, 1967), the genera of blue-greens incriminated have included Nodularia, Rivularia, Oscillatoria, Anabaena, Microcystis, Coelospherium, and Nostoc. Arkawa in 1960 and Lubetz in 1962 observed that hens and rats fed Chlorella may develop diarrhea and die (Jackson).

Iranian Waterborne Diseases

Due, in part, to unsanitary personal habits and the lack of adequate sanitary facilities, various intestinal disorders and even epidemics are not unusual in Iran. Treatment deficiencies and microbiological contamination of ground water were responsible for the majority of waterborne disease outbreaks between 1971 and 1974. Gunther (1978) reported that 64% of all outbreaks of dysentery and 48% of all illnesses due to the presence of disease in the population occur during the summer months--the period when outdoor activities are most common--through use of the semi-public water systems.

Feachem (1977) reviewed the various waterborne infectious diseases that pose important health problems in developing countries, and the means of transmission of these diseases. His conclusions were as follows:

Gastroenteritis. There is an increasing awareness of enteropathogenic E.coli serotypes as causative agents of gastroenteritis occurring among adults, in addition to its being a primary cause of infant diarrhea. Deb et al. (1977) reported that 88% of gastroenteritic outbreaks occur in children less than 2 years old, and 58% are in those only 7 to 12 months of age. Most of the reported instances of waterborne enteropathogenic E.coli infections have been related to the consumption of contaminated drinking water (WPCF, 1978: Bengtsson et al.; Danielsson, Laurell, Nordbring, & Sander;

Lanyi; Van Theil; Werner et al.). E.coli enters the aquatic environment from the discharge of fecal material introduced from some warm-blooded animal source (Geldreich, 1966; WPCF, 1978: Gustafson, Glantz). There are other bacteria, such as Yersinia, which can cause acute gastrointestinal illness. These bacteria were found by Eden et al. (1977) to be able to survive and possibly proliferate in unchlorinated well water. There is but little competition with other microorganisms. Aromonas, Citrobacter, and Enterobacter were repeatedly isolated from the same wells.

Salmonellosis. Salmonellosis is also a significant environmental health problem on a world-wide scale. Kalina (1977) and Sultanov and Solodovnikov (1977) indicated that there is rising incidence of salmonellosis in many countries and that the water is important in transmitting the illness, when used directly for drinking or indirectly for washing dishes and hands. Goyal et al. (WPCF, 1978) mentioned the occurrence of coliforms and salmonella in canal water and canal sediment. Domesticated farm animals and poultry are significant salmonella reservoirs (Nothinghum, in Mitchell, 1972).

Typhoid. Typhoid is specific for man and does not occur in other animals. The etiological agent for this disease is Salmonella typhymurium. Bahl (1976) reported on the effect of the piped water supply on the incidence of typhoid fever and diarrheal diseases in Luzak, Zambia. The incidence was

reduced in the city when the piped water supply was extended to urban and suburban self-help settlements.

Shigellosis. This is the most commonly identified cause of acute diarrheal diseases; exposure may be through person-to-person contact or poor-quality drinking water. Sultanov and Solodovnikov (1977) reported the existence of Shigella in public water supplies receiving no treatment and through seepage from sewer lines into water supply lines. The greatest incidence of dysentery was among children under 2 years of age. Summer and early autumn are peak periods for the spread of this disease. Persistence of Shigella is significantly better when the total bacterial population is low. It survives longer at low water temperatures. Another important factor that affects Shigella survival is water pH. Experiments indicate a growth of these organisms in media of 7.6 to 8.3 pH. Klebsiella strains, and the majority of coliform organisms tested at 37°C together with Shigella, caused interruption of Shigella exponential growth within 12 hours. The production of formic and acetic acids by coliform organisms in mixed cultures apparently exerted both bacteriostatic and bacteriocidal effects on Shigella strains (Hentges, in Mitchell, 1972).

Cholera. The bacterial pathogen Vibrio cholera can produce serious acute intestinal disease, causing death within a few hours after onset unless prompt medical treatment is available. Recorded evidence of cholera epidemics goes back

to 1563, as reported from India. At the turn of the century, cholera retreated to the Orient, only to return, first to Egypt in 1947, then to Iran and Iraq by 1964. In 1970, epidemics were reported in southern Russia and across the southwestern portion of Africa from Egypt to Guinea. This increased incidence of cholera in recent years may reflect a lack of international quarantine enforcement by some countries. Such countries often have primitive public water supplies and inadequate sanitary regulations. The international mobility of carriers in the world population, and the rapid transport of contaminated food and water by ships and aircraft, no doubt, facilitate the spread of epidemics.

The survival of Vibrio in the aquatic environment is related to various chemical, biological, and physical characteristics of water (Mitchell, 1972: Pesigan; Pillai & Menon; Shrewsbury & Barson). The chlorination of turbid, heavily polluted waters, without any prior treatment, has not produced a potable water supply free of cholera or salmonella organisms.

Pathogenic organisms, however, will be present in water degraded by a variety of pollutional discharges from warm-blooded animals. Their occurrence and magnitude do reflect the occurrence of prevalent diseases. It is absolutely necessary that further efforts be made to control water pollution and the accompanying danger of disease transmission from the potable drinking water sources.

CHAPTER III

DESIGN AND METHODOLOGY

The investigation was conducted during the summer of 1978 and winter of 1979 on an important source of drinking water--the ghanat. From the more than 100 ghanats in Tehran, 4 were selected for testing purposes. Located in the northern part of the city (Figures 2 and 3), the ghanats selected for sampling and study included those of Shahabad, Araj, Mobarakabad, and Hosseinabad.

The Ghanats of Study

Shahabad. The ghanat of Shahabad is located in the northwestern portion of the city of Tehran. Of the 2,872 people dwelling in this area (Table 1), most receive their domestic and irrigation waters from this ghanat. The bottom of this station, as well as that of others, is covered with a layer of clay and sand. The length of the conveyance canal is approximately 700 m, somewhat less than that of the other study areas; the wet portion of this canal or draining tunnel is 100 m. The depth of the head well (mother well) is 60 m. The yield of this ghanat is nearly constant during the different seasons of the year, with a flow of .5 cc of water per second (Table 2). The location of this study area is indicated in Figure 4.

SCALE 1:200,000

----- STUDY AREA IS ENLARGED IN FIGURE 3.

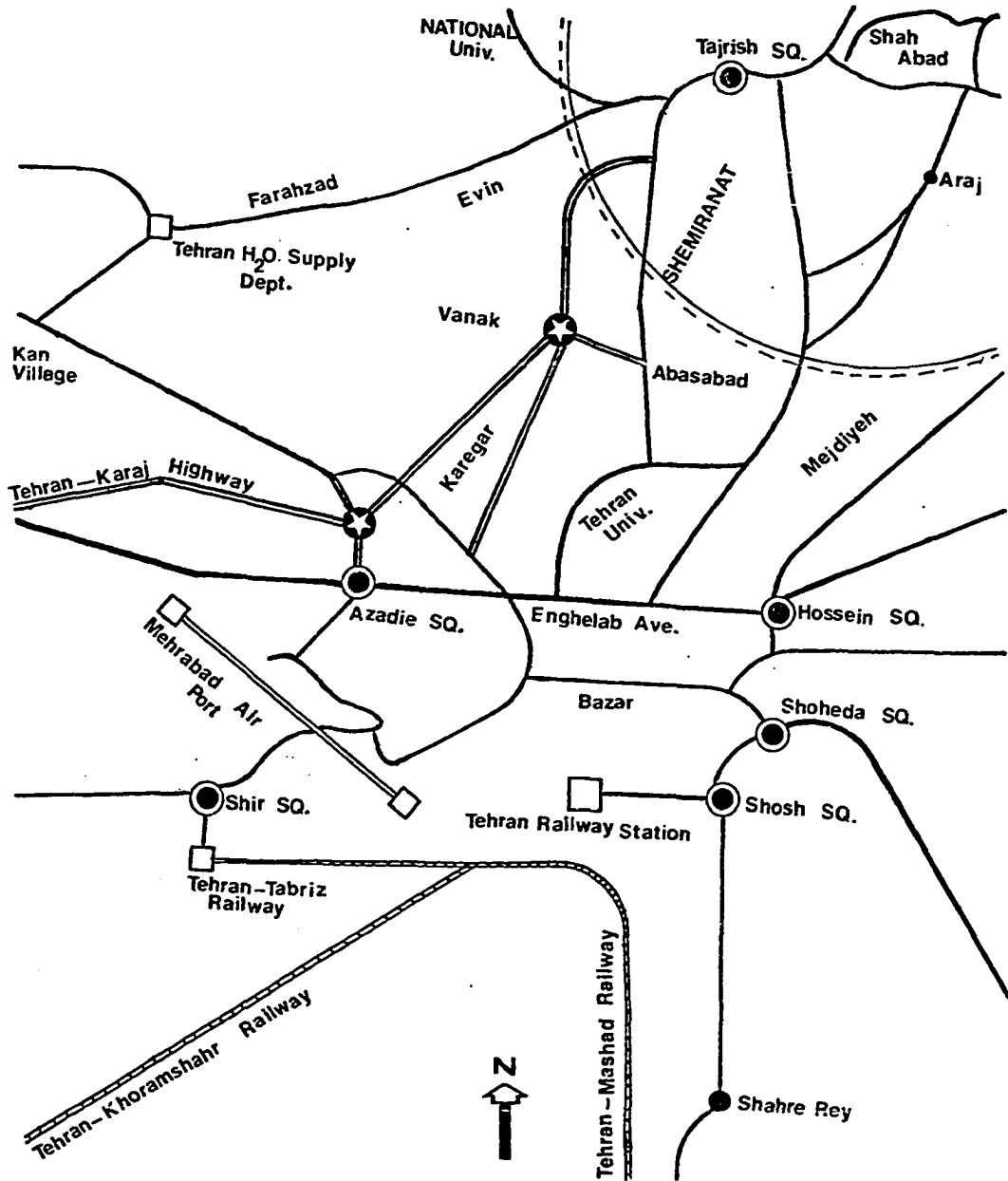


FIGURE 2. CITY OF TEHRAN.

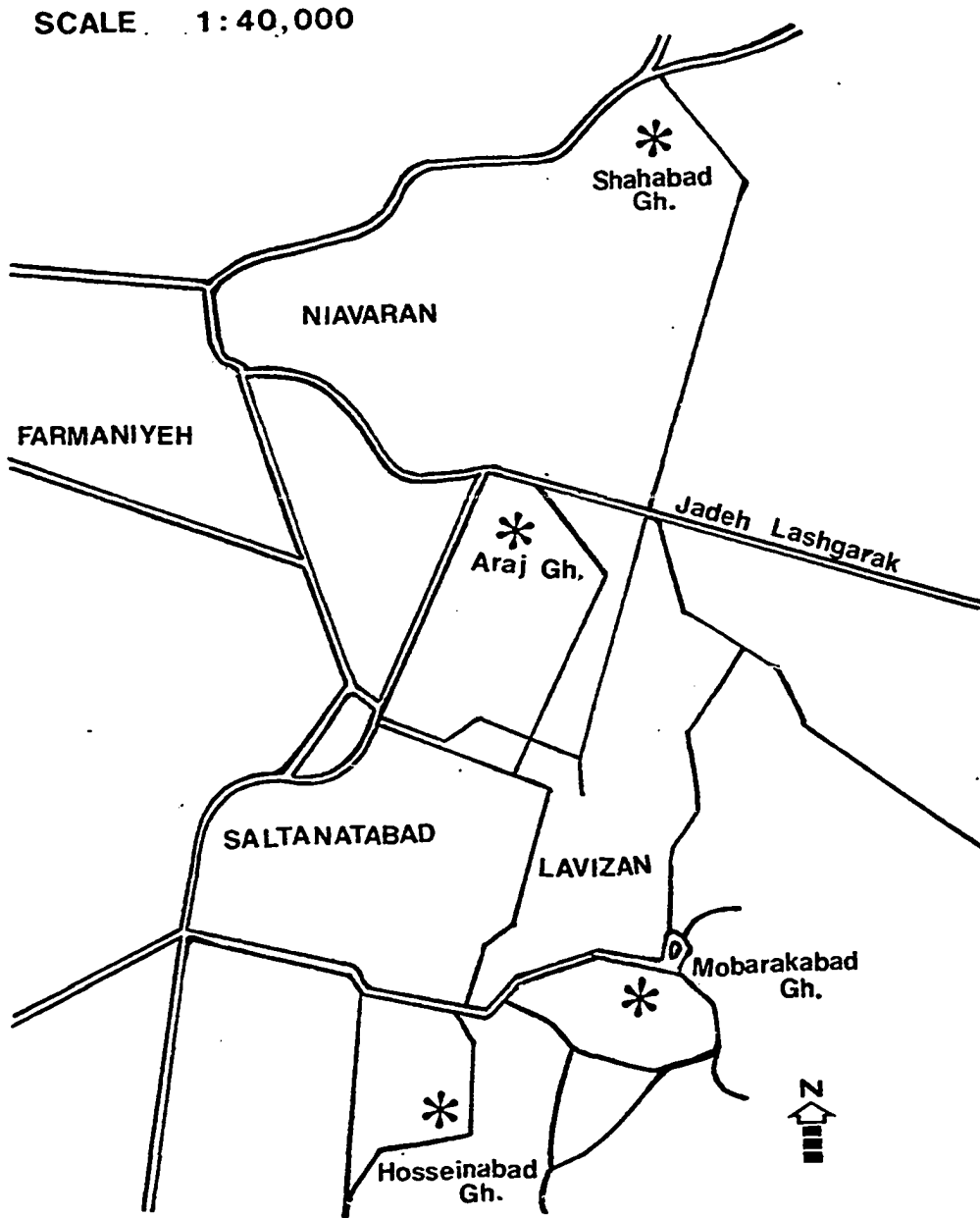


FIGURE 3. STUDY AREAS.

TABLE 1. HUMAN POPULATION IN THE VICINITY OF
EACH GHANAT, 1978.*

STATION	POPULATION
Mobarakabad	3,214
Shahabad	2,875
Hossenabad	1,815
Araj	1,405

* DATA FROM THE DEPARTMENT OF CENSUS .

TABLE 2. CHARACTERISTICS OF EACH GHANAT, 1979.*

Station	Length/m	Depth of mother well / m	Volume of water cc/sec
Shahabad	700	60	0.5
Araj	1,000	70	**
Mobarakabad	2,000	60	20
Hosseinabad	2,500	40	10

* DATA FROM MINISTRY OF WATER, TEHRAN.

** VARIOUS WITH THE SEASON.



FIGURE 4. SHAHABAD GHANAT

Araj. This ghanat is located 7 km south of Shahabad (Figure 5). During 1978, the Department of the Census estimated the population of this area to be more than 1,402 individuals (Table 1). As shown in Table 2, the discharge of water available from this ghanat is 20 cc/second, somewhat more than that of the other ghanats studied. The conduit of this ghanat from the head well which has a depth of 70 m to the discharge point is 1,000 m. Of importance to this study, samples of water were taken from the open portion of the ghanat, in front of a public restaurant. This fact probably had significance on the contamination of the water.

Mobarakabad. This study station is located next to Araj, which is located 9 km beyond Mobarakabad. Statistical data indicate that the highest population for this area is 3,214 individuals (Table 1).

The length of the conveyance canal for this ghanat is 200 m; the depth of the mother well is 60 m. The discharge varies with the season (Table 2). The water sample was taken from the open portion of the ghanat after it had passed through private land. The sample area was the one from which the public obtain their water requirements (Figure 6).

Hosseinabad. As shown in Figure 2, this ghanat is located below the above-mentioned stations. The length of this conduit is greater than that of the others (2,500 m), with a draining tunnel of 500 m. The depth of the mother well is less than that of the others, 40 m (Table 2). This



FIGURE 5. ARAJ GHANAT

*** Arrow indicates the location of step leading to
the water.**



FIGURE 6. MOBARAKABAD GHANAT

*** Arrow points to source of water sample.**

difference may be related to the greater length of the aquifer and the surface of the land, which is somewhat less than that of the other study areas. The yield of this ghanat is almost constant and amounts to 10 cc/second.

The Department of the Census estimated the population of this area to be 1,815 in 1978 (Table 1). Figure 7 indicates the location of this study area. Samples were collected during the summer of 1978 and winter of 1979.

Water samples from each of the study areas were collected in sterile vials and returned to the laboratory for further study. The variables considered were bacterial content, algal species and numbers, and physical and chemical content of the water. As a precaution, the samples were refrigerated prior to study in order to prevent changes in the contents. Tests were begun within 8-10 hours following the collection of the samples.

Bacterial and Yeast/Mold Studies

Total bacteria and total coliform content, fecal coliform numbers, and yeasts and molds were enumerated, using the Millipore booklet techniques. In order to make identifications on sources of coliforms (fecal or non-fecal), it was necessary to use the biochemical information available on coliform strains. The Indole, methyl red, Voges-Proskauer, and citrate tests were selected as the combination of reactions that would best determine whether the bacteria were

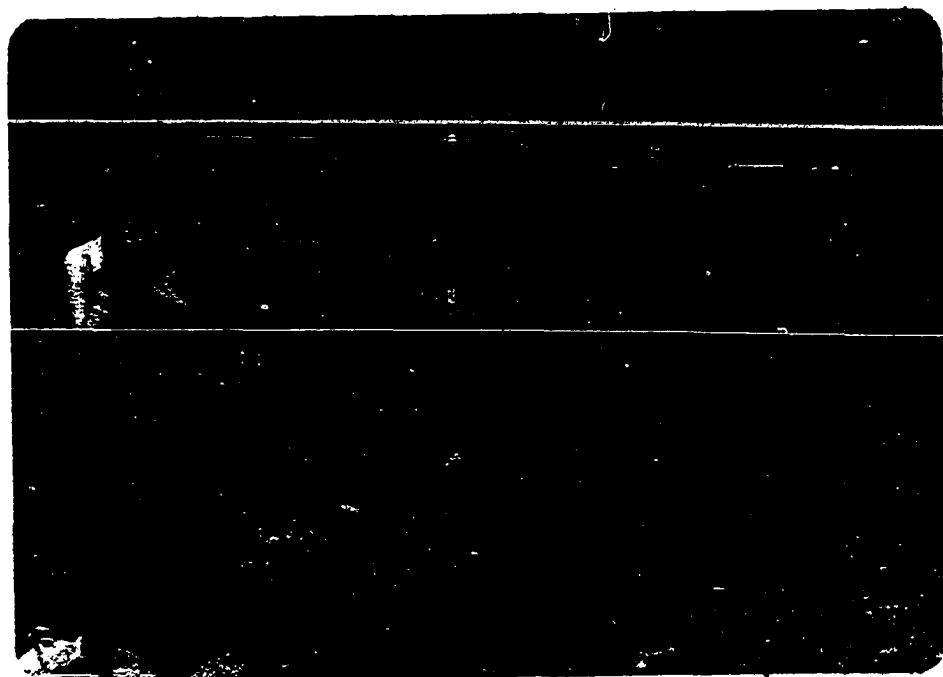


FIGURE 7. HOSSEINABAD GHANAT

fecal or non-fecal coliforms. This combination of four procedures has been designated the "IMV_iC test" (Geldreich, 1966). In this classification, IMV_iC types ++--, +---, and -+-- are considered to be of fecal origin, and types ---++, ---+-, and ----+ are considered to be of soil origin. The remaining 10 possible IMV_iC types fall into an intermediate group (Geldreich, 1966).

Algae Studies

At the same time that the bacterial collections were made, planktonic algae were collected. A plankton net of #25 mesh with holes .05 mm in diameter was used. It terminated in a small homeopathic vial of 34 ml capacity. Twenty liters of water were poured through the net, and the plankton was collected in the vial. Samples were preserved with 2-3 drops of preservative.

Three preservatives were used: (1) 4% buffered formalin solution, (2) formalin-propionic acid-alcohol (FPA) in standard proportions, and (3) Lugol's solution. These agents effectively killed the organisms and preserved them. A drop of glycerin was added to each vial to reduce possible damage to the sample, in case it were allowed accidentally to evaporate. After collection, the samples were stored at a temperature of 4°C, until examination.

For the initial identification, the algae were stained with certain specific dyes, such as hemotoxylin and fast

green 0. For the study of diatoms, a drop of the sample was spread on a microscope slide. The organisms were held over a flame and the water brought to a boil. After the smear was steamed, a drop of 5% glycerin was added, and the slide was then suitable for further study. For the study of filamentous algae and fungi, the glycerin method was used with some modifications. The killed and fixed materials were stained with iron hemotoxylin. They were then placed in a 10% aqueous glycerin solution and put into an oven until the fluid was evaporated and the materials were ready for mounting and further study. For differentiating between blue-green algae and green algae, fast green 0 was used in an iron alum metachrome stain which stained the nuclei a deep green while the cytoplasm was lighter (Edmondson, 1959). Several taxonomic references were valuable aids to generic identification. These included: Bold and Wynne (1978), Cook (1972), Eddy and Hadson (1961), Edmondson (1959), Needham and Needham (1962), Palmer (1963), Prescott (1968, 1970), Round (1973), Stanier et al. (1963), Trainor (1978), and Weber (1971). Sampling identification was checked by Dr. Clarence J. Goodnight, and by graduate students George Duba and Victor Gonzales.

The Sedgewich-Rafter slide was the basic apparatus and technique used for quantitative and qualitative analysis of plankton. The Sedgewich-Rafter chamber was utilized. It is a chamber 50 mm long by 20 mm wide, and 1 mm deep; the total volume is 1 ml. Due to the depth of the chamber, only 10X

magnification is suitable. For higher magnification (45X), which was at times necessary for identification, a 24 x 60 ml #1 cover glass was placed across the Sedgewich-Rafter cell. With a pipette, 1 ml of well-mixed sample was transferred into the open corner of the chamber. The cover slip was rotated into place as the cell was filled. The clump count was used and, with all filamentous or colonial organisms present, the undersides of the cover slips were examined. The number of these organisms was added to the total count.

To calculate the concentration of organisms, a strip count was made. Twelve strips (whole slide) were examined in each of several slide preparations. The results were averaged for each sample and reported as the number of units per milliliter:

$$\text{No. per ml} = \frac{C \times 1000 \text{ mm}^3}{L \times D \times W \times S},$$

where

C = actual count of organisms (tally),

L = length of each strip (S-R cell length), mm,

D = depth of the strip (S-R depth), mm,

W = width of a strip (Whipplegrid image width),
mm,

S = number of strips counted (Standard Methods, 1975).

The data thus gathered were used as a basis for calculating the number of organisms in the entire sample. For this reason, a correction factor for the concentration of

the 20 l water sample in the 34 ml vial was determined.

A measure of the component of diversity due to distribution of individuals among the species was calculated from the above data. Those major components which were calculated are described below.

The distribution of individuals among the species was calculated. For this purpose, the Shannon-Weaver function for calculating mean diversity (\bar{d}) was used:

$$\bar{d} = \frac{C}{N} (N \log_{10} N - \sum n_i \log_{10} n_i) ,$$

where

$C = 3.321928$ (converts base 10 log to base 2),

$N =$ total number of individuals,

$n =$ total number of individuals in i^{th} species.

Mean diversity, \bar{d} , is affected both by richness of species and by the distribution of individuals among the species and may range from zero to $3.321928 \log N$.

In nature, equality of species is quite unlikely, so Lloyd and Ghelardi proposed the term "equitability" for comparing the number of species (s) in the sample with the number of species expected (s') from a community that conforms to the MacArthur model:

$$e = \frac{s'}{s} ,$$

where

$s =$ number of taxa in sample,

$s' =$ tabulated value.

Physical and Chemical Analyses

In order to see the effect of important chemical elements in the previously mentioned pollutants, chemical analyses were determined at each of the four ghanats. These analyses involved quantitative determinations for dissolved oxygen, pH value, carbon dioxide, calcium hardness, chloride, free acidity, and nitrogen nitrate.

Water samples were taken 30 cm below the surface of the water. Analyses for determination of the above chemical elements were carried out according to the Hach Colorimeter Methods Manual (1977).

In conjunction with the bacterial, planktonic, and chemical enumeration of the waters, limnological observations such as water and air temperature were enumerated at the same time. A quality-grade mercury-filled centigrade thermometer was placed into the water and in the ambient air. After a period of time sufficient to permit a constant reading, the temperature was recorded to the nearest $1/2^{\circ}\text{C}$.

CHAPTER IV

FINDINGS

Bacteria and Yeasts/Molds

The results for bacteriological parameters are as follows: Total bacteria, total coliform bacteria, fecal coliforms, and yeasts/molds are shown in Table 3 and in Figures 8, 9, 10, and 11, respectively. Table 3 shows the total number of the above microorganisms per 100 ml of sample during August 1978 and February 1979 in the four study areas: Shahabad, Araj, Mobarakabad, and Hosseinabad.

Total bacteria

According to the data shown in Table 3, the total number of bacteria was higher in the summer period than in winter in all four ghanats; however, the level of total bacteria colonies was unusually higher for Mobarakabad in both seasons.

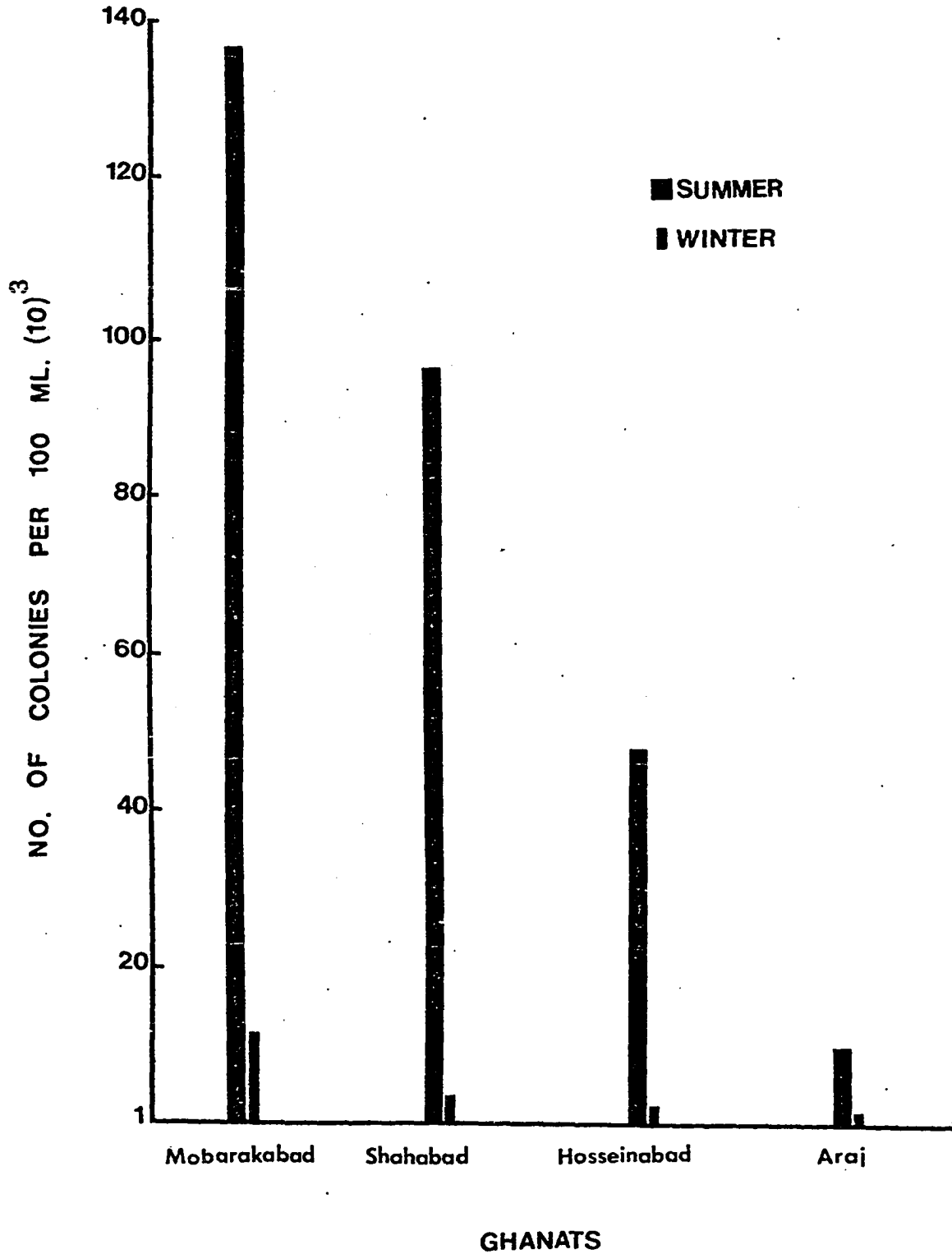
Figure 8 gives a better comparison of total number of bacteria among the four stations and differences in level of bacteria during summer and winter. The number of bacteria in Mobarakabad was almost 10 times more than that of Araj, which had the lowest in both seasons.

The second and third stations with the highest total number of bacteria were Shahabad and Hosseinabad, respectively. During winter, however, with the exception of

TABLE 3. NUMBER OF BACTERIA, YEAST AND MOLDS FOR EACH GHANAT, 1978 AND 1979.

STATION	TOTAL COUNT/100 ml.		TOTAL COLIFORM/100 ml.		FECAL COLI. /100 ml.	YEAST & MOLDS/100 ml.
	Summer	Winter	Summer	Winter	Winter	Summer
Mobarakabad	138,500	12,900	332	255	38	22,600
Shahabad	96,100	2,800	722	650	282	244
Hosseinabad	48,600	2,100	610	480	182	455
Araj	10,700	2,000	185	126	86	4,675

FIGURE 8. TOTAL NUMBER OF BACTERIAL COLONIES
PER 100 ML. OF SAMPLE, SUMMER 1978; WINTER 1979.



of Mobarakabad, there was little difference for total bacteria reading in the three other stations. All three were below 2,800 per 100 ml.

Total coliforms

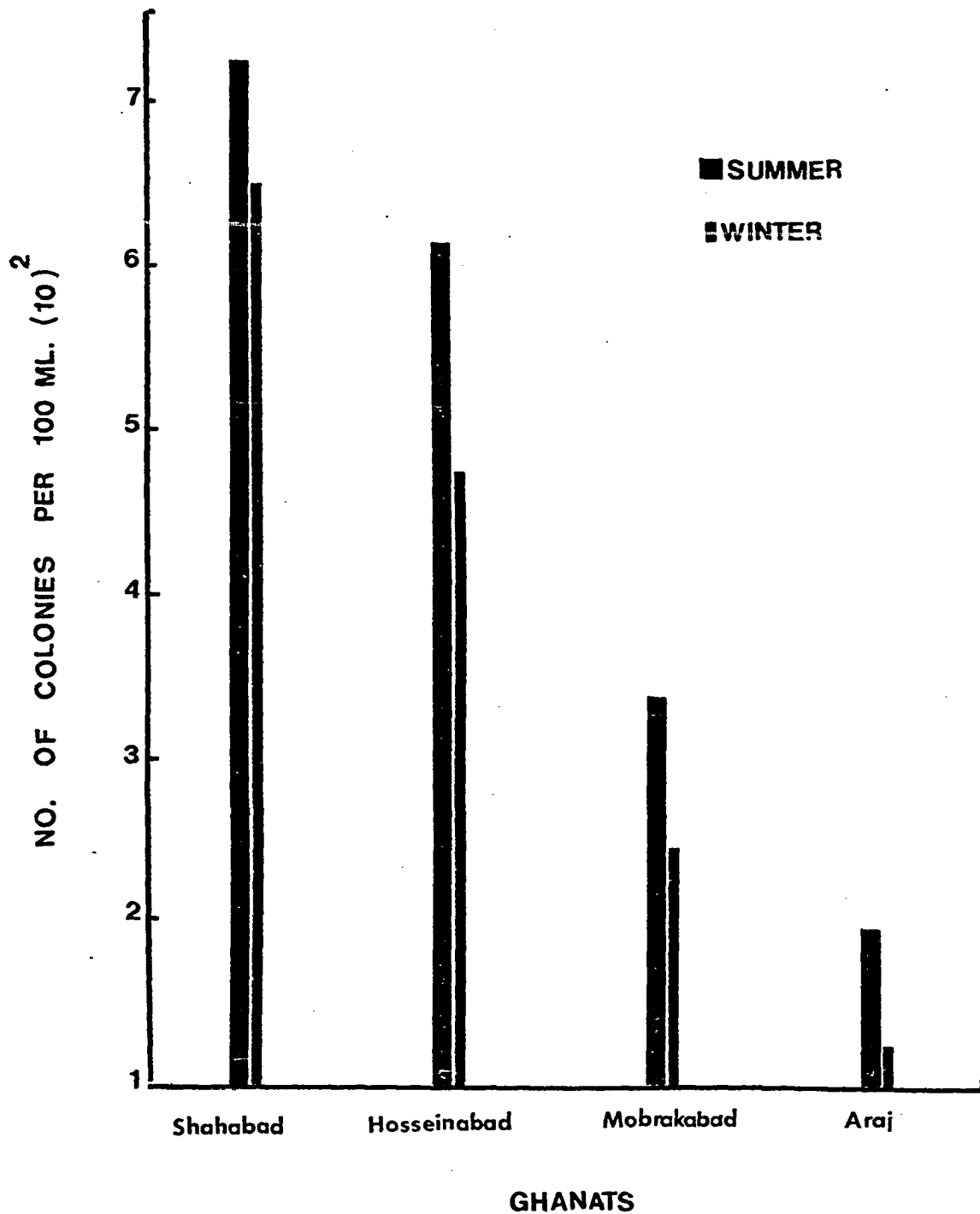
This group of bacteria is the most frequently used for the examination of water quality. The basis for using the coliform bacteria as indicators of fecal pollution is that the primary natural habitats of these bacteria are the intestines of homeothermic animals (Lynch & Poole, 1979).

With reference to Table 3, there are fewer coliform bacteria for all stations for both seasons than total bacterial count. In winter there are fewer coliforms in all stations than in summer. The high total count at Mobarakabad is obviously not due to coliforms. In fact, the coliform count at this station is third lowest; the greatest count is seen at Shahabad.

The data in Table 3 were used to draw Figure 9, which shows the total number of coliform colonies for each station during summer and winter. One can see that the dramatic drop in total bacterial count in the winter is not seen for all coliforms. The difference between winter and summer is not very great.

As was mentioned above, there was an increase in the number of total bacteria and coliform groups for all stations during the summer of 1978 (Figures 8 and 9, respectively).

FIGURE 9. TOTAL NUMBER OF COLIFORM COLONIES
PER 100 ML. OF SAMPLE, SUMMER 1978; WINTER 1979.



The fluctuation was probably related to the resumption of outdoor activities by the population and the increased use of water systems. The bacteria causing the dramatic changes due to the seasons are not coliforms. The exact types of bacteria present remain to be determined.

Fecal coliforms

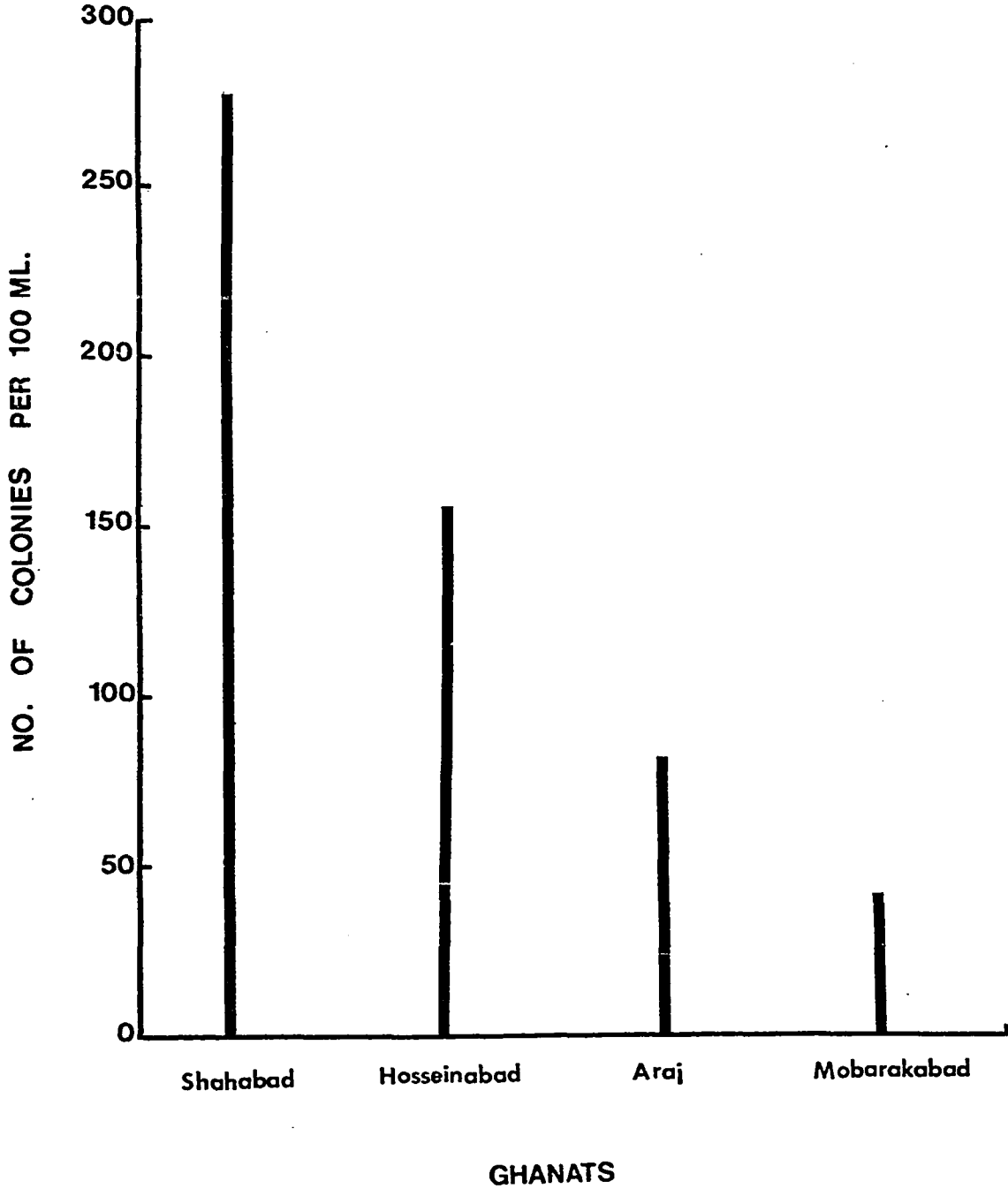
Fecal coliform organisms may be considered as indicators of recent fecal pollution by homeothermic animals (Wolf, 1972). This assumption is probably true for Escherichia coli, which occurs in large numbers in feces (Lynch & Poole, 1979).

The population of fecal coliform bacteria was enumerated during the winter of 1979 (Table 3). It is interesting to note that Mobarakabad, with the highest level of total bacteria, has the next to lowest coliform count and the lowest number of fecal coliforms. Perhaps the water at this station is the safest for human consumption.

There are several reports documenting the statement that the high non-coliform population has been implicated in the suppression of fecal bacterial growth (Geldreich et al., 1972; Lavrumov et al., 1958; Wang et al., 1966). This competition between total bacteria and fecal coliform bacteria is possibly true for the ghanat of Mobarakabad.

The data in Table 3 were used to draw Figure 10, which shows the density of fecal coliform bacteria for all stations during the winter of 1979. Shahabad shows the highest amount

FIGURE 10. TOTAL NUMBER OF FECAL COLIFORM COLONIES PER 100 ML. OF SAMPLE, FEBRUARY 1979.



of fecal coliforms (282 per 100 ml). Hosseinabad is the second station with higher fecal bacteria (182 per 100 ml). Araj, with 86 fecal coliform colonies per 100 ml of water, is next to Mobarakabad, which contains a lesser number of fecal coliform bacteria than the other stations (38 per 100 ml). These counts do not correlate with the total bacteria counts seen in Table 3. Other than Mobarakabad, Shahabad had a high total count; however, this station also had high fecal coliform count.

In many countries the total and fecal coliform counts are used to assess the health risk posed by pathogenic microorganisms in water. The "norms" relating to this subject are given by the World Health Organization, which recommends that there be an absence of fecal coliforms per 100 ml of unchlorinated potable water. Only a low content of coliform bacteria (10 non-fecal coliforms) in 100 ml of water may be tolerated in occasional samples. Water containing higher numbers of bacteria should be forbidden for drinking purposes unless it is absolutely impossible to find another source.

According to Table 3, the data for total coliform bacteria and fecal coliforms in the study areas would indicate that none of these stations has water of high enough quality for drinking purposes.

The major source of contamination by total coliform bacteria and fecal coliforms in ghanats is probably due to human activity in the area, but this study cannot be conclusive in

in this statement.

According to the Department of the Census in Tehran, Iran, the data in 1978 show that the human population of 3,214 in Mobarakabad is higher than that of Shahabad, with 2,875. With reference to Table 3, the combined total of coliform and fecal coliform readings is lower in Mobarakabad; however, the total bacterial count is very high in Mobarakabad. Some other type of human contamination must be occurring here. Since there is a high density of coliform bacteria in Shahabad and high fecal coliform count in this station, it is probably due to contamination from human sources.

Population statistics for Shahabad (2,875 people), Hosseinabad (1,815 people), and Araj (1,405 people) apparently conformed with the fecal coliform data, which were 282/100 ml, 182/100 ml, and 86/100 ml of sample for these ghanats, respectively.

Differentiation of bacteria and possible sources. The basis of using the coliform bacteria as an indicator of fecal pollution is that a large number of these bacteria are found in feces. However, there are other coliforms which can grow in nonanimal environments such as soil, and some of them are transitory and occur on plant surfaces and even in industrial effluents. These bacteria can be classified as an intermediate group (Duncan & Razzel, 1972).

The differentiation of coliform groups and their origin was indicated with a small range of biochemical tests which

are known by the acronym IMV_iC , which stands for the following tests: I = Indole, M = methyl red, V_i = Voges-Proskauer, and C = citrate. IMV_iC is therefore used to fit the coliform isolated into a simple classification system.

The IMV_iC reactions of coliform species for study areas are shown in Table 4. According to Table 4, in the classification of IMV_iC , type ++-- is considered to be of fecal origin, the situation which happened in Shahabad and Araj. Another possibility of IMV_iC test for Araj was --++, which shows that some of the coliforms originated in the soil. The IMV_iC types +-++ in Mobarakabad, and ++-+ in Hosseinabad, fall into an intermediate group of bacteria.

The result of this test can be another answer to the unusually low level of fecal coliforms (38) in Mobarakabad compared with other ghanats. According to the above test, the coliform bacteria in this station were not of fecal origin.

Yeasts and molds

Yeast and mold colonies in each ghanat during the summer of 1978 are presented in Table 3. According to Table 3, the level of yeasts and molds is not so high per milliliter as the number of bacteria in total. There is a broad range among the four stations tested. Again, Mobarakabad had 4 to 100 times more yeasts/molds than the other stations. Araj was 1,000 and 2,000 higher in count than the remaining two

TABLE 4. DIFFERENTIATION OF COLIFORM GROUP OF ORGANISMS IN STUDY AREAS, FEBRUARY 1979.*

STATION	IMV ₁ C TEST				ORIGIN
	Indole	Methyl red	Voges-Proskauer	Citrate	
Mobarakabad	+	-	+	+	Intermediate
Shahabad	+	+	-	-	Fecal
Hosseinabad	+	+	++	+	Fecal
	+	+	++	+	Intermediate
Araj	-	-	+	+	Soil
	+	+	+	-	Fecal

* DATA OBTAINED FROM LABORATORY OF HYDROLOGY FACULTY OF PHARMACY.

stations. This may be accounted for by the slightly alkaline pH of the water samples, which ranged between 7.55 and 7.85 in the study areas (Cook, 1972).

Figure 11 gives a better illustration of the range of yeast and mold numbers in all four ghanats, with the highest amount in Mobarakabad (22,600). This figure is almost 100 times more than the level of these organisms in Shahabad, the station with the lowest number of yeasts and molds (244). Araj and Hosseinabad are second and third, with 4,675 per 100 ml and 455 per 100 ml, respectively. Table 3 shows an inverse relation between fecal coliforms and yeasts/molds. This is a very interesting finding, and much remains to be learned.

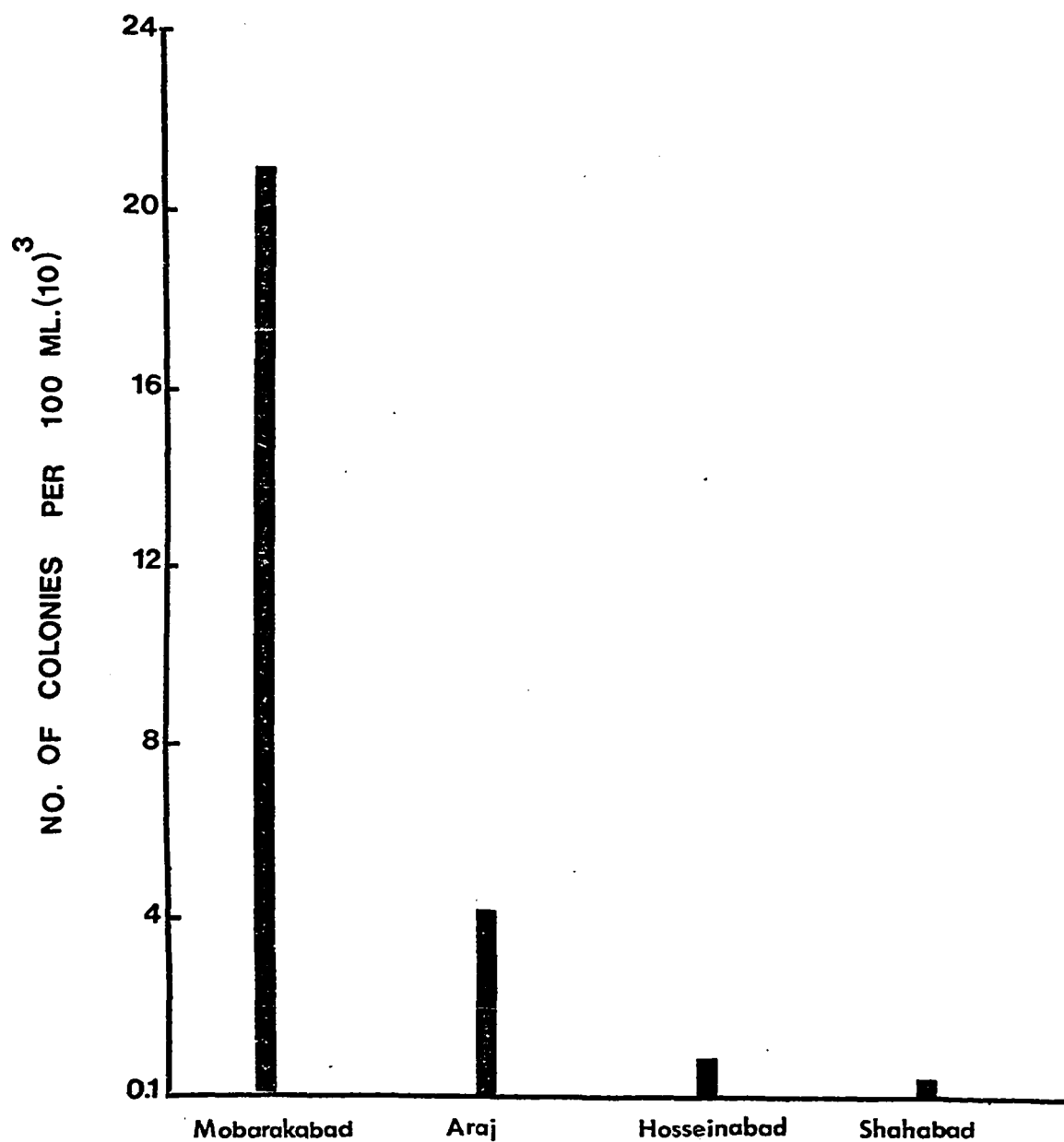
Planktonic Algae

The determination of water quality by the use of planktonic algae is widely known and has certain values.

Tables 5 and 6 indicate planktonic algal population during summer and winter, respectively. Through the summer of 1978, the number of phytoplankton was high, especially for Chrysophyta and Chlorophyta. The population decreased slightly during the winter period. According to Tables 5 and 6, the number of individuals in each phylum was highest for Mobarakabad, especially during summer.

Tables 7, 8, 9, and 10 indicate the number and kinds of planktonic algae at each ghanat. The data show there are

FIGURE 11. TOTAL NUMBER OF YEAST AND MOLDS
PER 100 ML. OF SAMPLE, AUGUST 1978.



GHANATS

TABLE 5. PLANKTONIC ALGAL POPULATION (NO. PER ML.), FOR EACH GHANAT, AUGUST 1978.

STATION	Chlorophyta	Chrysophyta	Cyanophyta	Pyrrophyta	Euglenophyta
Mobarakabad	203	285	119	23	—
Araj	126	240	24	12	—
Hosseinabad	79	151	46	36	—
Shahabad	51	24	20	21	9

TABLE 6. PLANKTONIC ALGAL POPULATION (NO. PER ML.), FOR EACH GHANAT, FEBRUARY 1979.

STATION	Chlorophyta	Chrysophyta	Cyanophyta	Pyrrophyta	Cryptophyta
Mobarakabad	14	30	20	5	1
Araj	10	25	15	10	1
Hosseinabad	12	52	19	4	—
Shahabad	12	7	12	27	11

TABLE 7. COMPOSITION OF PLANKTONIC ALGAE IN SHAH-
ABAD (NO. PER ML.), SUMMER 1978; WINTER 1979.

PHYLUM	GENERA	SUMMER 1978	WINTER 1979
CHLOROPHYTA			
	Botryococcus	9	—
	Chlorococcum	—	4
	Chlorella	11	8
	Eustrium	6	—
	Gonium	18	—
	Oedogonium	7	—
CHRYSOPHYTA			
	Asterionella	11	6
	Diatoma	4	—
	Cymbella	4	—
	Synedra	5	1
CYANOPHYTA			
	Coelospherium	6	—
	Lyngbya	—	4
	Microcystis	14	3
	Oscillatoria	—	5
PYRROPHYTA			
	Glenodini	10	12
	Peridinium	11	15
EUGLENOPHYTA			
	Trachelomonas	9	—
CRYPTOPHYTA			
	Cryptomonas	—	11
NO. PER ML.		125	69

TABLE 8. COMPOSITION OF PLANKTONIC ALGAE IN MOBARAK-
ABAD (NO. PER ML.), SUMMER 1978; WINTER 1979.

PHYLUM	GENERA	SUMMER 1978	WINTER 1979
CHLOROPHYTA			
	Chaetophora	-	1
	Chlorella	75	8
	Chlocoocum	51	-
	Cosmarium	-	1
	Oedogon	-	1
	Rhizoclonium	-	1
	Stigeoclonium	34	-
	Tetraderon	16	4
	Ulothrix	4	-
	Volvox	23	-
CHRYSOPHYTA			
	Asterionella	4	5
	Cocconies	22	-
	Cymbella	24	2
	Diatoma	-	18
	Frustularia	52	-
	Navicula	14	-
	Synedra	169	5
CYANOPHYTA			
	Coelospherium	21	6
	Microcystis	95	8
	Oscillatoria	3	3
	Spirulina	-	1
PYRROPHYTA			
	Glenodinium	23	5
EUGLENOPHYTA			
	Phacus	-	1
NO. PER ML.		630	70

TABLE 9. COMPOSITION OF PLANKTONIC ALGAE IN HOSSEIN-
ABAD (NO. PER ML.), SUMMER 1978; WINTER 1979.

PHYLUM	GENERA	SUMMER 1978	WINTER 1979
CHLOROPHYTA			
	Chlorella	48	—
	Cladophora	—	1
	Coelostrum	—	2
	Oedogonium	6	—
	Palmella	—	2
	Spirogira	—	1
	Stigeoclonium	18	5
	Tetraderon	7	—
	Ulothrix	—	1
CHRYSOPHYTA			
	Asterionella	9	4
	Chlamydomonas	—	15
	Cocconies	12	—
	Cymbella	60	—
	Diatoma	20	12
	Dinobryon	6	—
	Navicula	24	16
	Rhoicosphemia	11	—
	Stephanodiscus	—	3
	Synedra	9	2
CYANOPHYTA			
	Anabaena	—	5
	Coelospherium	9	7
	Microcystis	25	6
	Nostocopsis	—	1
	Oscillatoria	7	—
	Spirolina	5	—
PHYRROPHYTA			
	Peridinium	36	4
NO. PER ML.		312	87

TABLE 10. COMPOSITION OF PLANKTONIC ALGAE IN ARAJ
(NO. PER ML.), SUMMER 1978; WINTER 1979.

PHYLUM	GENERA	SUMMER 1978	WINTER 1979
CHLOROPHYTA	Cladophora	10	-
	Chlorella	91	-
	Oedogonium	13	-
	Pedastrum	-	3
	Stigeoclonium	12	-
	Tetraderon	-	7
CHRYSOPHYTA	Asterionella	9	-
	Cocconies	23	2
	Chlamydomonas	-	22
	Cymbella	108	-
	Dinobryon	-	1
	Gyrosigma	4	-
	Nitzschia	4	-
	Rhoicosphemia	5	-
	Stephanodiscus	5	-
	Synedra	47	-
	Tabellaria	35	-
CYANOPHYTA	Calothrix	1	-
	Coelospherium	11	1
	Gloeotrichia	4	5
	Microcystis	4	3
	Nostoc	4	6
	Oscillatoria	5	-
PYRROPHYTA	Glenodinium	12	7
	Peridinium	-	3
CRYPTOPHYTA	Cryptomonas	-	1
NO. PER ML		402	61

some changes in the composition of the algal community. Some of them have been eliminated during the winter, such as Chlorella, Oedogonium, Cymbella, Coconies, and Roicosphemia, which were more common during summer. Some others, which could tolerate cold water and increased in number, were Frustularia, Chlamydomonas, Lyngbaya, Anabaena, and Nostocopsis. Cryptomonas, in phylum Cryptophyta, were identified only during the winter period.

A total of 47 genera was found in all four ghanats. The two most abundant genera in the phylum Chlorophyta were Chlorella and Oedogonium. Asterionella, Cymbella, and Synedra were characteristic of Chrysophyta. Oscillatoria, Microcystis, and Coelospherium were the dominant forms of the phylum Cyanophyta.

Throughout the summer period the predominant genus, Cymbella, was similar for all stations. In contrast, winter community samples were completely dominated by Asterionella for Mobarakabad, and Chlamydomonas for Araj and Hosseinabad.

So far as pollution is concerned, it is important to mention that among different algae there are many genera which are tolerant of pollution. Among tolerant algae, we can mention some of the forms such as Chlorella, Oscillatoria, Microcystis, and different diatoms such as Cymbella and Asterionella. These algae are of significance in the recovery of water because of their conversion of the polluted substances into nourishment for algal cells which are a

source of nutrition for the aquatic fauna (Palmer, 1963). Various genera of each of these algae prefer waters which are high in organic material. The association of them is typical of hard water, which is characteristic of the aforementioned ghanats.

Water samples were at the optimum temperature for growth of the above algae (10-16°C), since they are essentially cold-water organisms.

Figures 12, 13, 14, and 15 show a comparison of planktonic algae during summer and winter in each study area. The graphs indicate the higher population of some algal groups during summer for each station separately.

To gain an understanding of this situation, percentage composition of plankton communities (Figures 16 and 17) and the composition of dominant genera of Chrysophyta (Figures 18 and 19) were illustrated for stations during the summer of 1978 and winter of 1979.

Figures 16 and 17 show that, among five phyla of planktonic algae, Chlorophyta in summer and Pyrrophyta in winter have the highest percentage (40%) of composition of algae for Shahabad. There was not too much difference among other phyla for this station. According to the above figures, Chrysophyta has the highest percentage in both summer and winter for the three other stations. Chlorophyta in summer, and Cyanophyta in winter, have the second highest percentages of composition of planktonic algae for the mentioned ghanats.

FIGURE 12. COMPOSITION OF PLANKTONIC ALGAE IN SHAHABAD, SUMMER

1978; WINTER 1979.

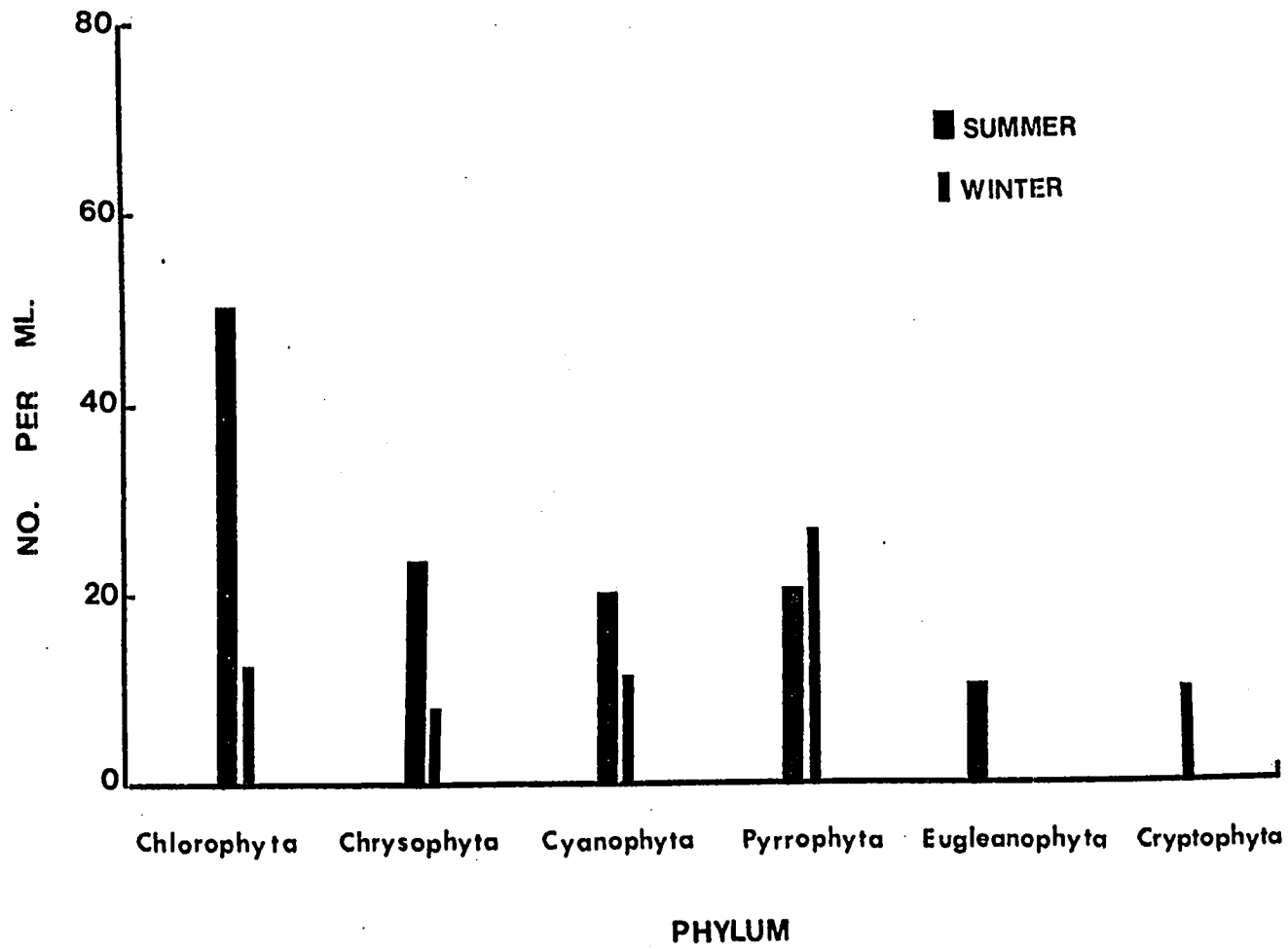


FIGURE 13. COMPOSITION OF PLANKTONIC ALGAE IN
MOBARAKABAD, SUMMER 1978; WINTER 1979.

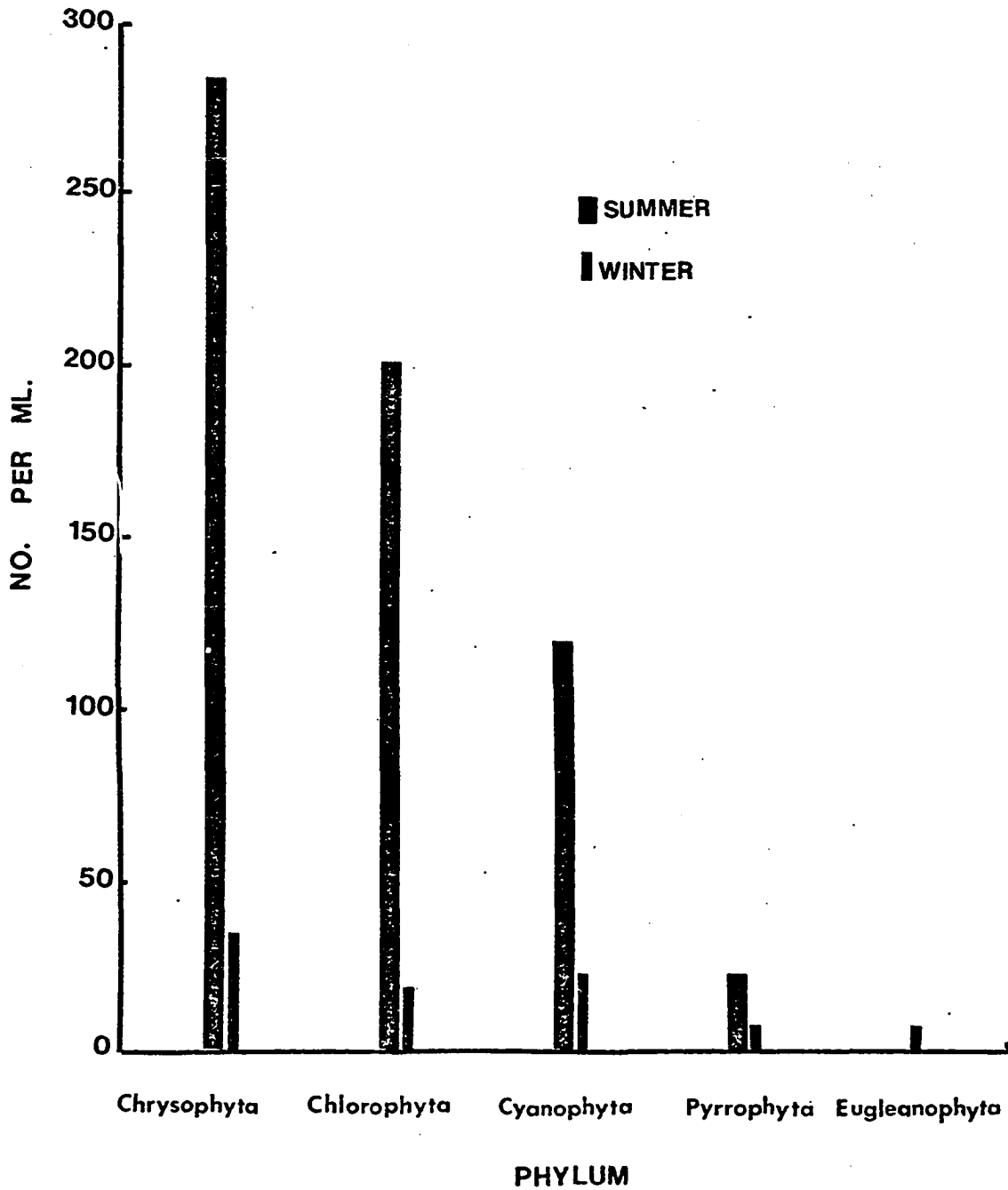


FIGURE 14. COMPOSITION OF PLANKTONIC ALGAE IN HOSSEINABAD, SUMMER 1978; WINTER 1979.

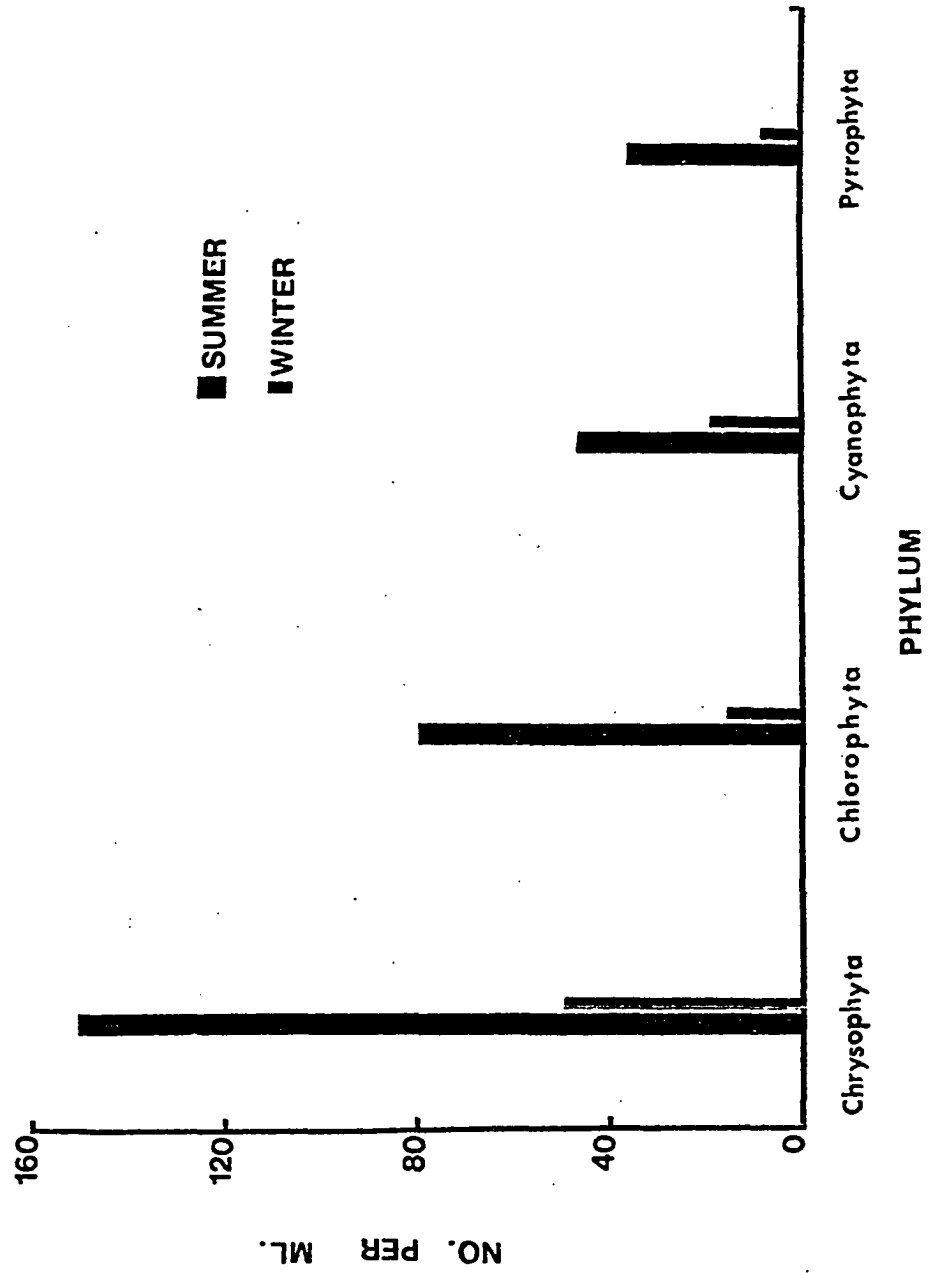


FIGURE 15. COMPOSITION OF PLANKTONIC ALGAE IN
ARAJ, SUMMER 1978; WINTER 1979.

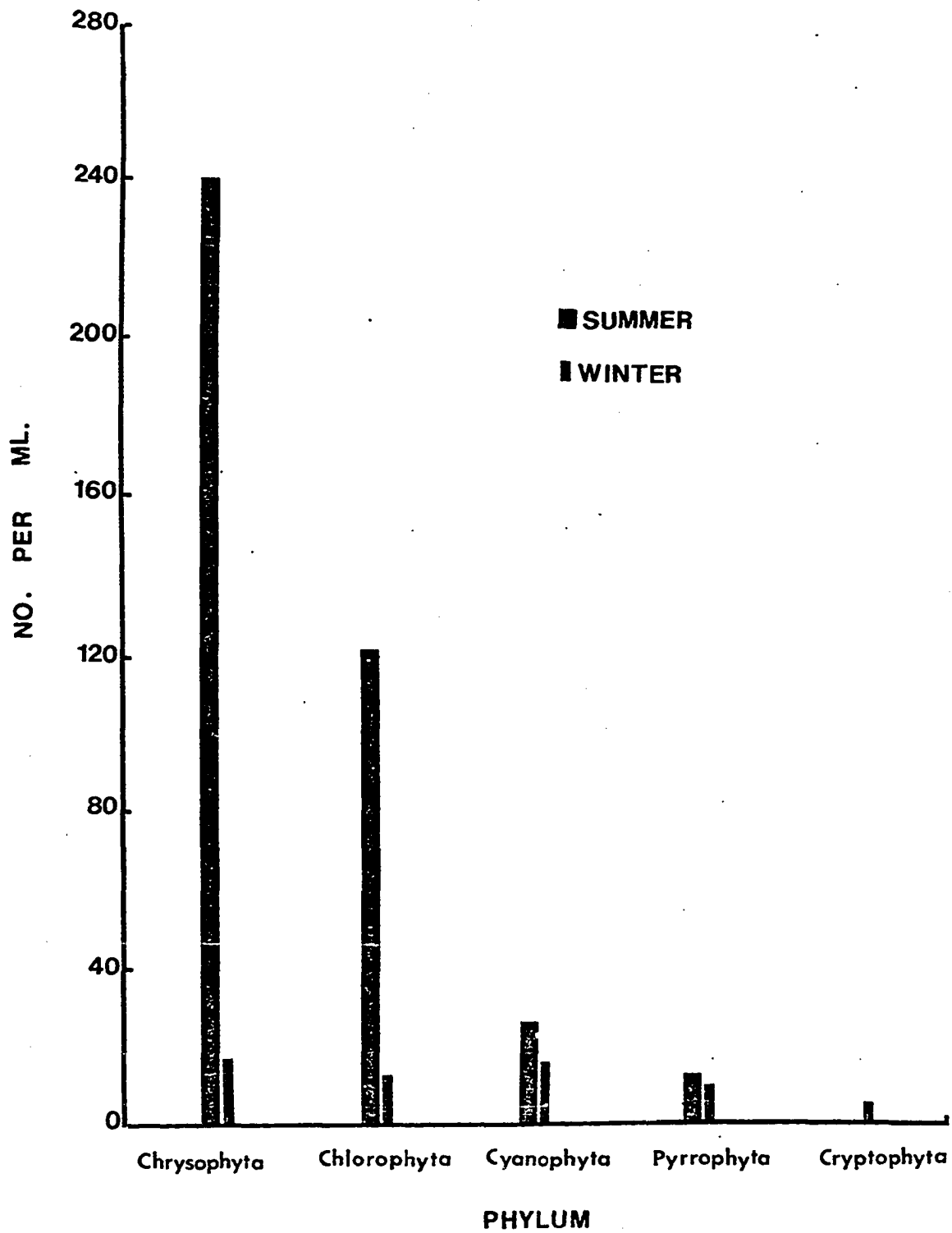


FIGURE 16. PERCENTAGE COMPOSITION OF PLANKTONIC ALGAE FOR WATER SAMPLES, SUMMER 1978.

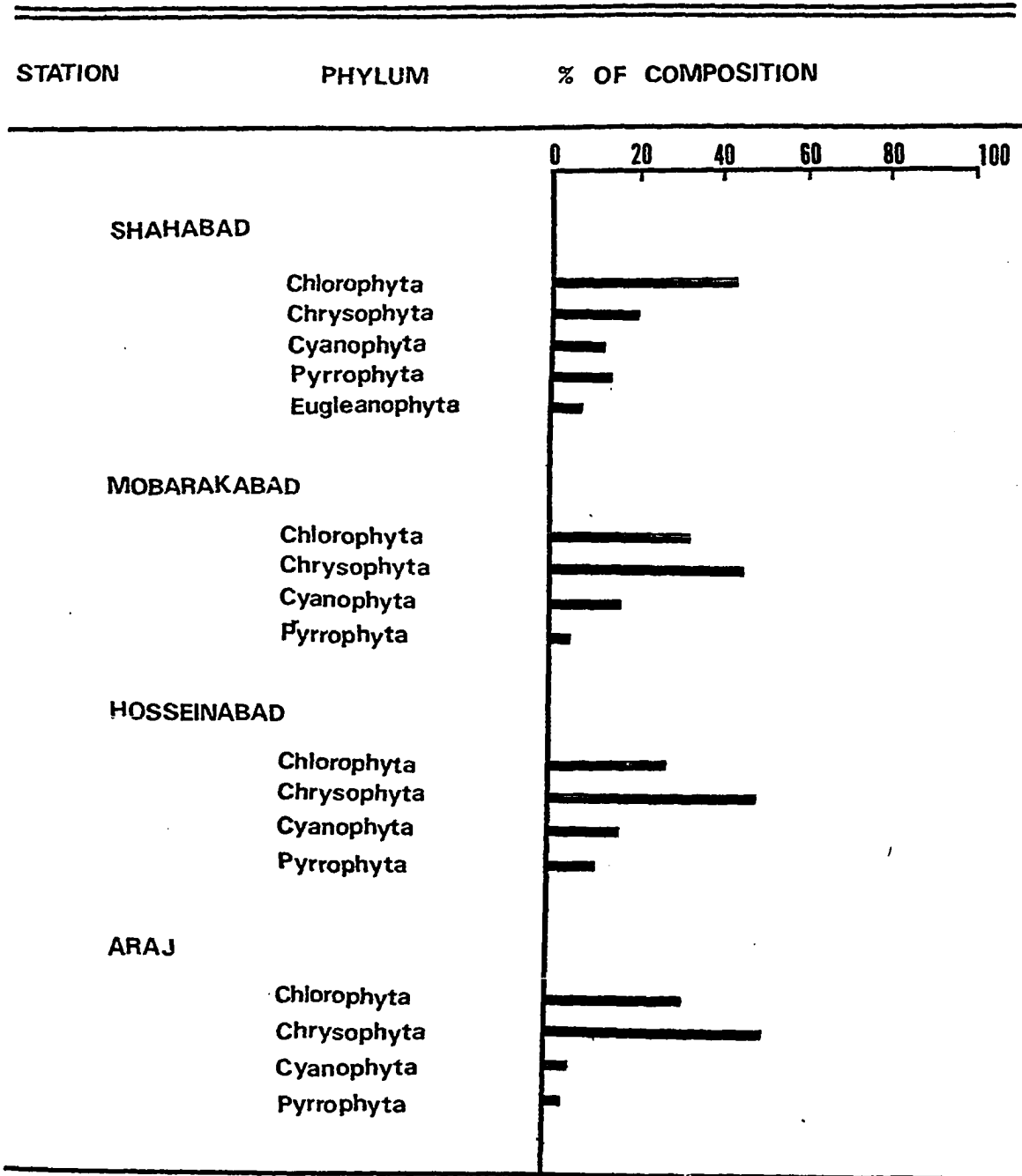
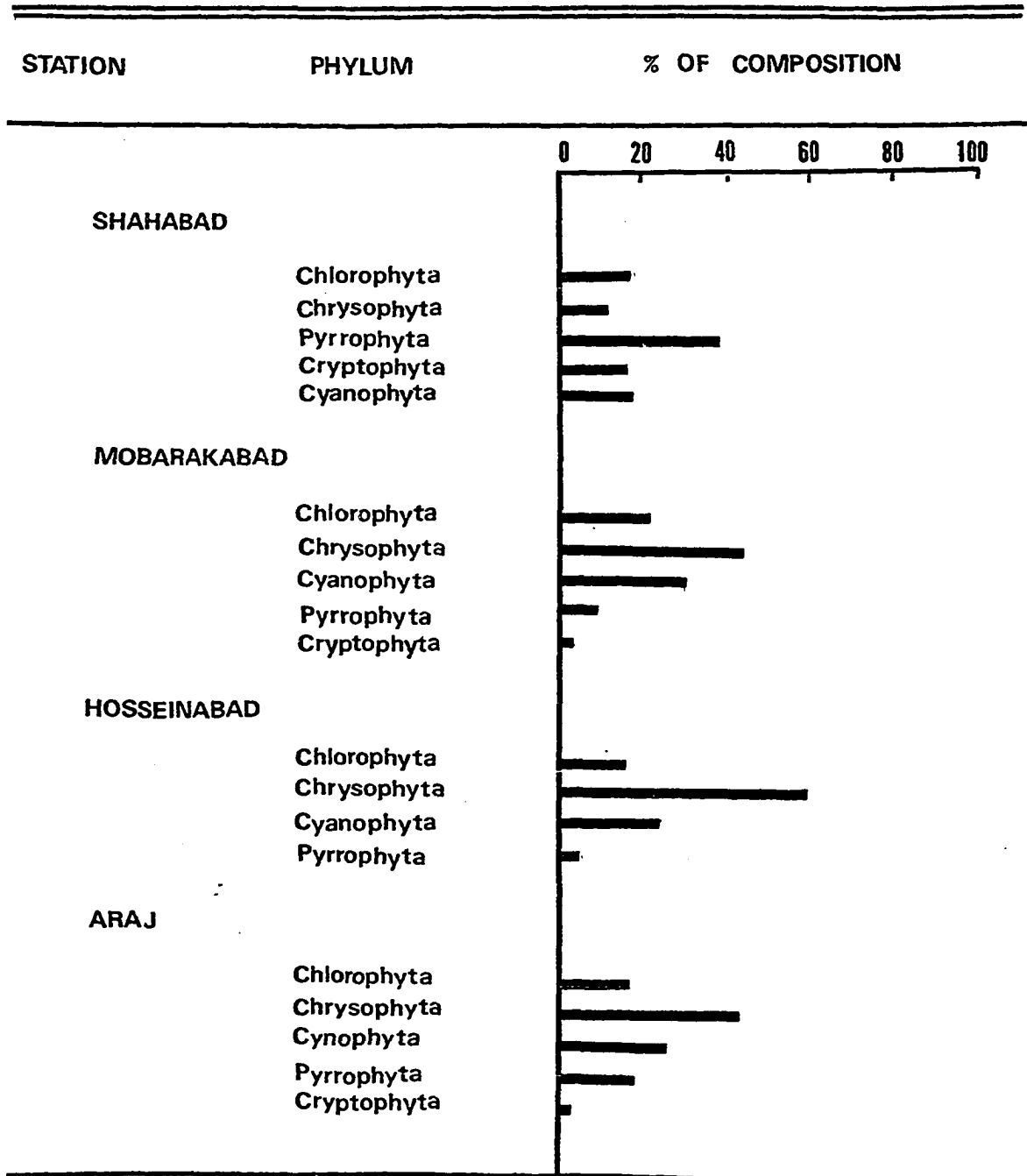


FIGURE 17. PERCENTAGE COMPOSITION OF PLANKTONIC ALGAE FOR WATER SAMPLES, WINTER 1979.



With reference to Figures 18 and 19, there are not too many different genera of Chrysophyta in Shahabad. Asterionella has the highest percentage for both summer and winter. In the other ghanats, there is a variety of Chrysophyta. During summer, Cymbella was the dominant form for Hosseinabad and Araj, and Synedra had the highest percentage for Mobarakabad. In the winter period, Navicula and Chlamydomonas had the same amount (30%) for Hosseinabad. The percentage of Frustularia was higher than others for Mobarakabad; and the dominant form for Araj, with over 80% of composition, was Chlamydomonas.

Most diatoms are reported to favor low light and temperature regimes, the conditions which exist in ghanats. Many investigators have suggested that these factors are the triggering mechanisms for the increased growth (Patrick & Reuner, 1966; Smith, 1950).

In regard to the richness of species and the distribution of individuals among the species, the Shannon-Weaver index was used to evaluate mean diversity (\bar{d}), and the Lloyd-Geldreich index was employed to determine equitability (e). Equitability is calculated by evaluating the component of \bar{d} which is due to the distribution of individuals within the species.

The data in Tables 7, 8, 9, and 10 were used to calculate \bar{d} and Table 11 to calculate e . The statistical data show that the variety of algal form undergoes fluctuation

FIGURE 18. PERCENTAGE COMPOSITION OF DOMINANT GENERA OF CHRYSOPHYTA FOR GHANATS, SUMER 1978.

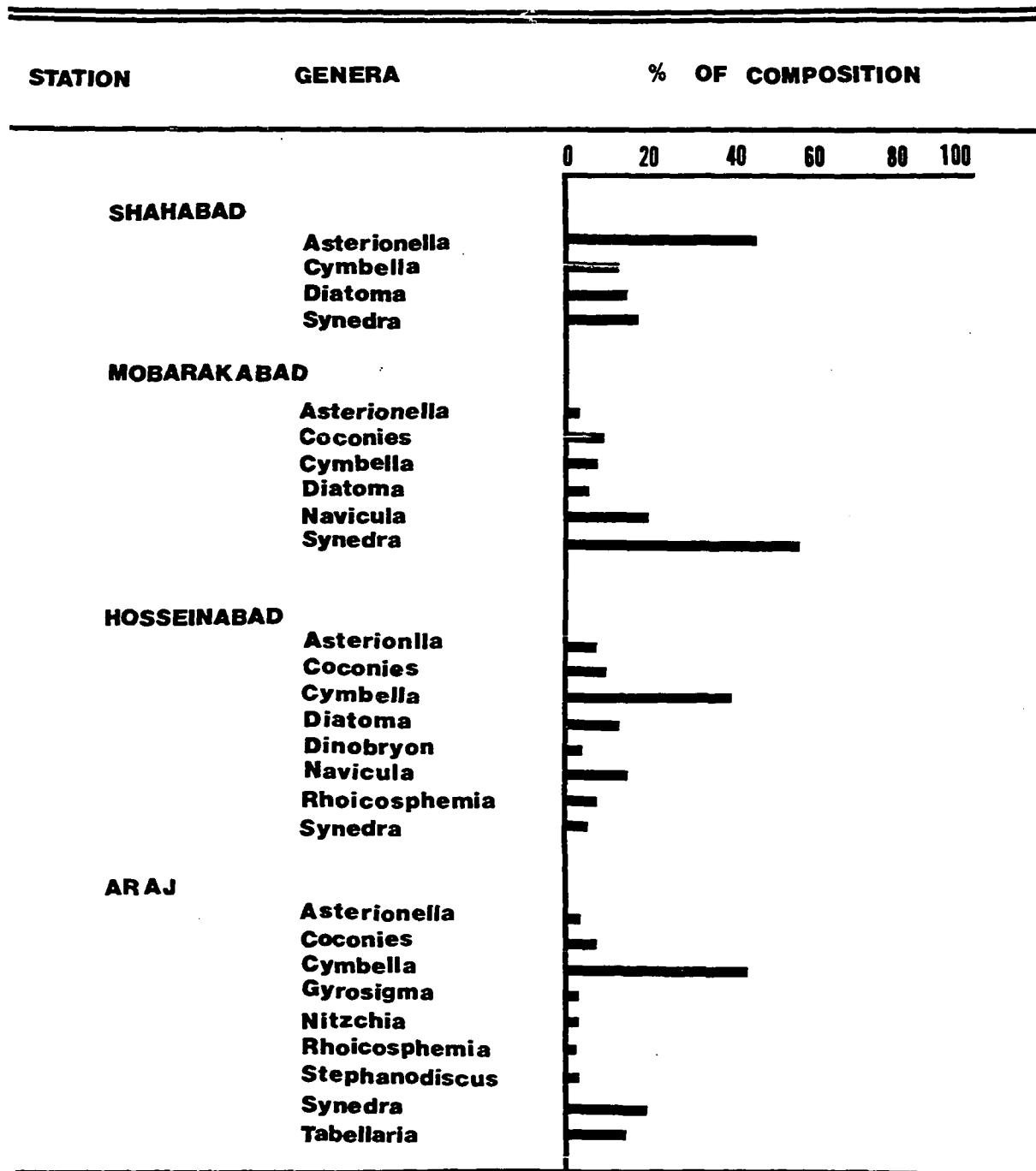


FIGURE 19. PERCENTAGE COMPOSITION OF DOMINANT GENERA OF CHRYSOPHYT FOR GHANATS, WINTER 1979.

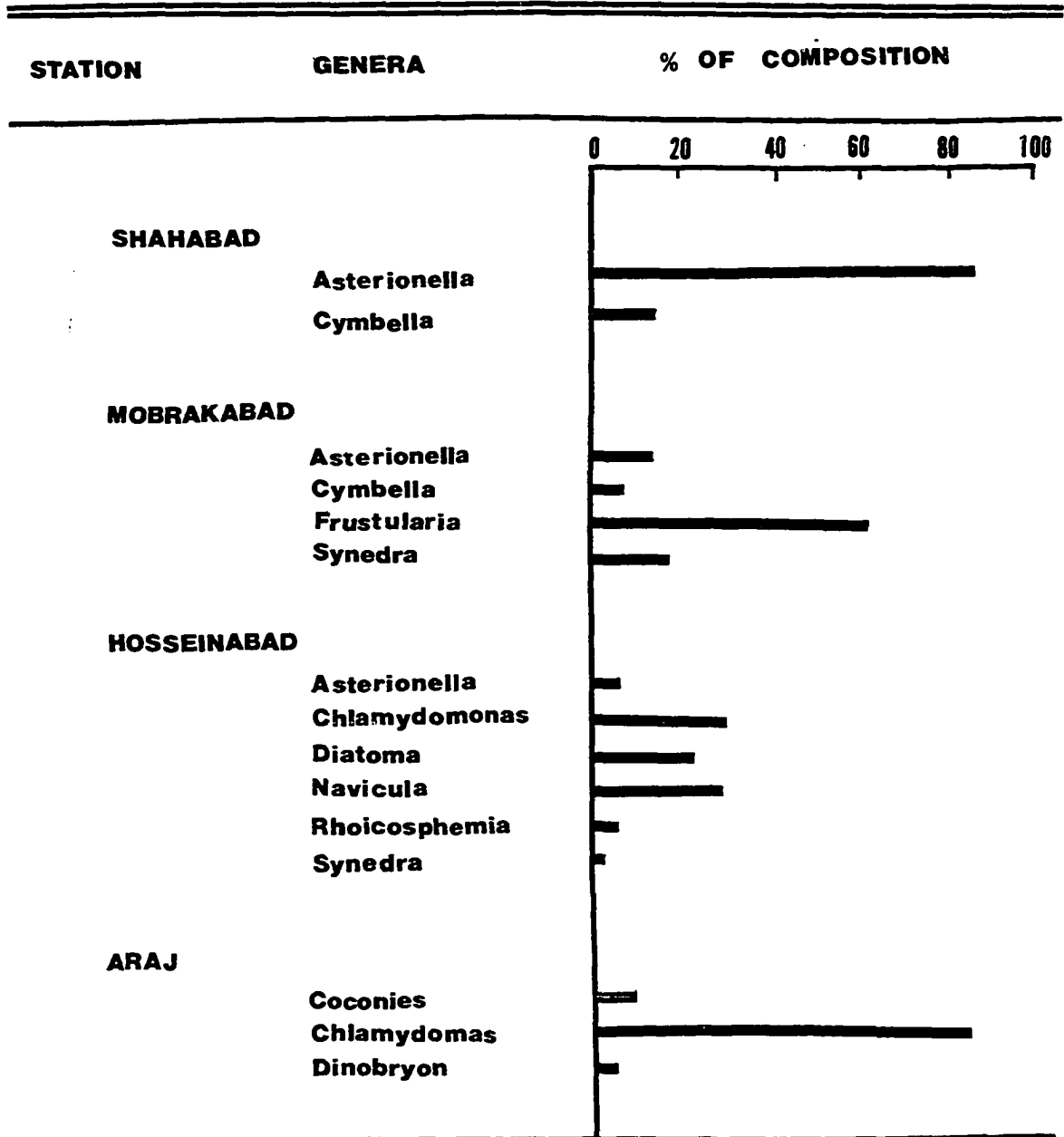


TABLE 11. MEAN DIVERSITY (\bar{d}), AND EQUITABILITY (e) OF PLANKTONIC ALGAE FOR GHANATS, SUMMER 1978; WINTER 1979.

STATION	Summer 1978		Winter 1979	
	\bar{d}	e	\bar{d}	e
Mobarakabad	3.35	0.87	3.29	0.87
Araj	3.33	0.77	2.90	0.83
Hossenabad	3.50	1.00	3.29	0.94
Shahabad	3.21	0.93	2.70	0.90

both in number and species for each station separately.

Figure 20, indicating mean diversity for planktonic algae at the four ghanats, shows a higher \bar{d} in summer than in winter for all study areas. The highest \bar{d} was found for Hosseinabad and the lowest one for Shahabad, both in summer and winter.

Wilhm (1970) and Wilhm and Dorris (1968) reported that values for \bar{d} between 1 and 3 are in areas of moderate pollution, the condition which was found in Shahabad ($\bar{d} = 2.7$) and Araj ($\bar{d} = 2.9$) in February 1979. Values above 3 are usually obtained in unpolluted waters. At all stations, \bar{d} was greater than 3 during the summer period. In winter, for Hosseinabad and Mobarakabad, \bar{d} still remained over 3, but for Shahabad and Araj the value of \bar{d} was less than 3.

Equitability is reported to be more sensitive than mean diversity, and, as calculated, it may range from 0 to 1. Slight levels of degradation have been found to reduce e below .5 and generally to range from .0 to .3.

As shown in Figure 21, Hosseinabad had the highest value of 3, and Araj had the lowest one both in summer and winter. As long as e was above .5, there was no significant level of degradation in the ghanats in regard to this parameter.

FIGURE 20. MEAN DIVERSITY FOR PLANKTONIC ALGAE FOR EACH

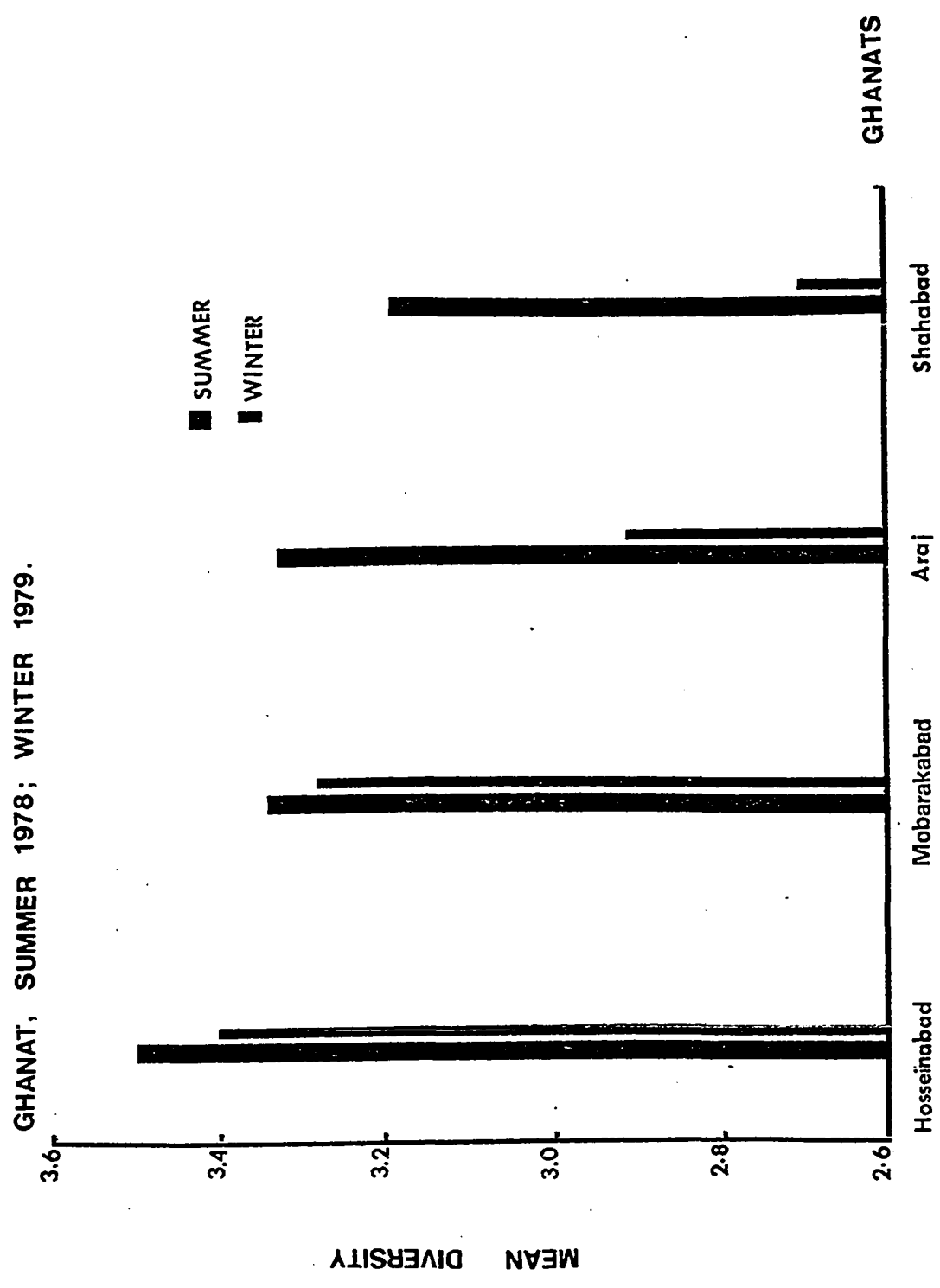
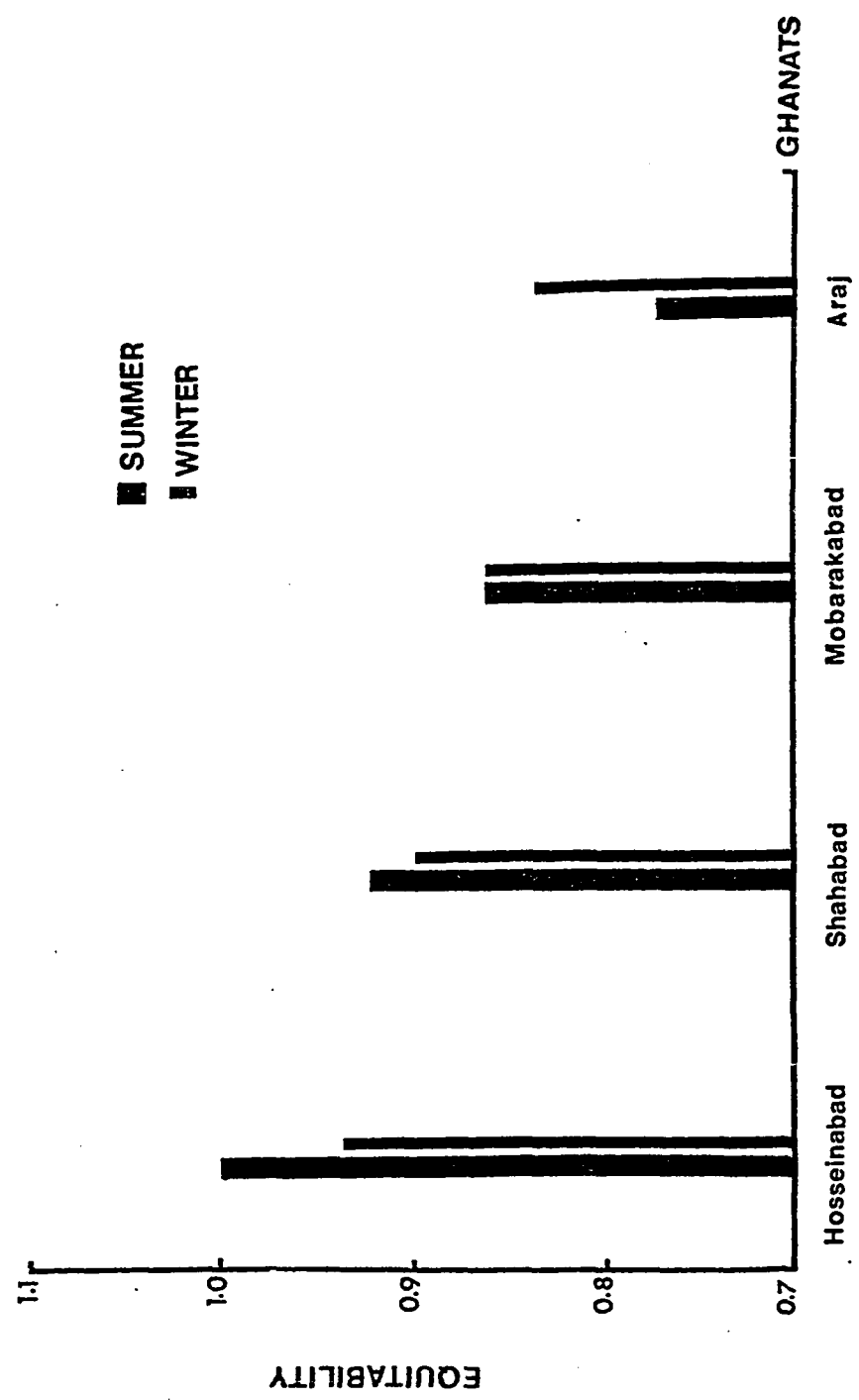


FIGURE 21. EQUITABILITY OF PLANKTONIC ALGAE FOR EACH GHANAT, SUMMER 1978; WINTER 1979.



Physical and Chemical Parameters

Dissolved oxygen (DO)

The DO test is one of the most important parameters for an organism's growth. The effect of oxidation of waters, the suitability of water for organisms, and the progress of self-purification can all be estimated from DO content. DO is essential in aerobic biological process and its relation to oxidation-reduction (redox) potentials (Standard Methods, 1975).

To calculate the oxygen balance for a given body of water requires knowledge of the various sources of, and demand for, oxygen. Oxygen can enter a body of water from the atmosphere; it is also produced within the water as a product of algal photosynthesis. There is a demand for oxygen due to the aerobic respiration of microorganisms in the water.

Table 12 shows the level of oxygen in the four stations, with the highest level of DO in Araj (13 p.p.m.) and the lowest level in Shahabad (9 p.p.m.). There are no major differences in DO levels between the four ghanats (Figure 22).

For a good body of water, the DO content should be in the 8-15 p.p.m. range. According to the European norms, the minimum permissible oxygen concentration is about 5 p.p.m. All stations were above this minimum level.

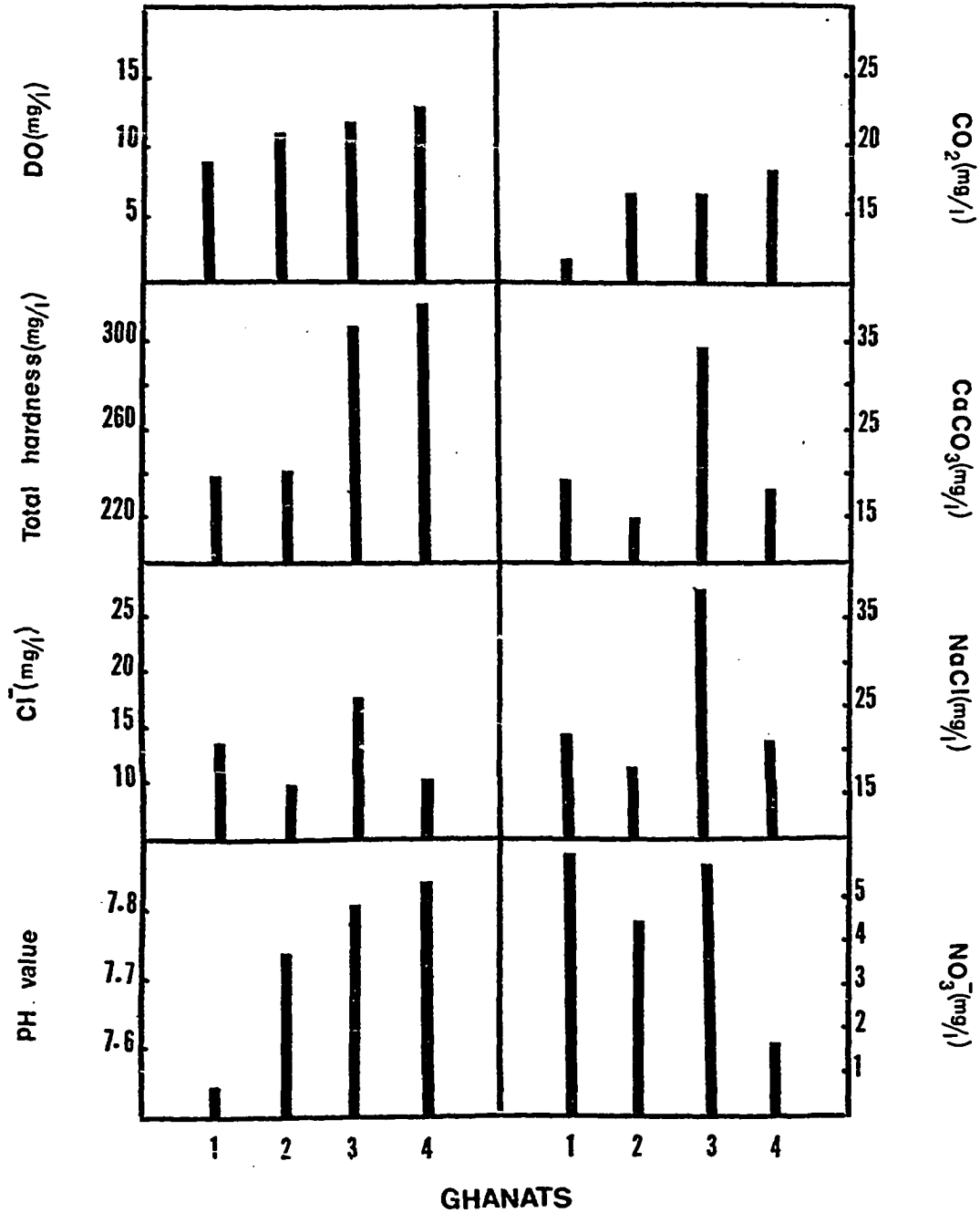
TABLE 12. CHEMICAL AND PHYSICAL ANALYSES, FEBRUARY 1979.

Station	O ₂	CO ₂	pH	NO ₃ ⁻	Cl ⁻	Na Cl	CaCO ₃	Total hardness	Electrical conductivity $\mu\text{s}/\text{cm}$
Araj	13	18	7.85	1.74	13	21.4	18.3	312	411
Hosseinabad	12	16	7.80	5.72	23.5	38.7	33.1	307	349
Mobarakabad	11	16	7.75	4.03	10.6	17.5	14.9	240	336
Shahabad	9	12	7.55	5.72	13.5	22.3	19.3	242	596
International norms	5	*	7-8.5	50	250	-	-	**	-

*The presence of CO₂ is not innocuous to health.

** Water of medium quality has up to 300 P.P.M. total hardness. Acceptable quality of water has up to 500 P.P.M. of hardness.

FIGURE 22. QUANTITATIVE DETERMINATION FOR
 CHEMICAL PARAMETERS, WINTER 1979 (1. Shahabad , 2.
 Mobarakabad, 3. Hosseinabad , 4. Araj).



Carbon dioxide (CO₂)

Another parameter that is significant in aquatic environment is CO₂, because of its role in photosynthetic process and in pH equilibria. CO₂ occurs naturally in water as a product of aerobic or anaerobic decomposition of organic matter; it also is absorbed readily from the atmosphere.

According to Table 12, the level of CO₂ was generally greatest in Araj (18 p.p.m.) and least in Shahabad. Mobarakabad and Hosseinabad had the same CO₂ level (Figure 22). The range seen between Shahabad and the others is greater. All measurements correspond to the stations' DO content.

Usually ground waters such as ghanats carry higher amounts of CO₂ than surface waters, and liberate it rather rapidly on contact with the atmosphere. International norms recommended that the presence of CO₂ is innocuous to human health.

pH value

Shahabad station was slightly less alkaline (7.55) than the other ghanats (Table 12). Only very minor variations occurred in the pH values among the stations. The highest value was reported for Araj (7.85).

Due to the high level of dissolved salts, water tends to be high in alkalinity. One important parameter that influences pH value is the concentration of CO₂ related to

total mineralization.

According to international norms, potable water must have a pH value between 7 and 8.5. As shown in Figure 22, the four stations were within these limits.

Nitrate (NO_3^-)

As indicated in Table 12, the NO_3^- concentration was generally greater in both Hosseinabad and Shahabad (7.72 p.p.m.), and lowest in Araj (1.74 p.p.m.). Acceptable limits for NO_3^- based on international norms are less than 50 p.p.m. All stations were well below this level (Figure 22).

Razeghi et al. (1975) reported that the concentration of N-NH_3 was uniformly distributed in all zones of Tehran, and they indicated that local contamination originated from domestic sewage.

It is important to mention that nitrate-nitrogen is the principal source of nitrogen for algal growth.

Chloride (Cl)

The concentration of chloride was not high as compared to international norms (did not exceed 250 p.p.m.). The highest concentration of this ion appeared in Hosseinabad (23.5 p.p.m.), and the lowest appeared in Mcbarakabad (10.6 p.p.m.), as shown in Table 12 and Figure 22.

Sodium chloride (NaCl) and
calcium carbonate (CaCO₃)

Table 12 shows that the amount of these two salts was higher in Hosseinabad (NaCl, 38.7 p.p.m.; CaCO₃, 33.1 p.p.m.) and were lowest in Mobarakabad (NaCl, 17.5 p.p.m.; CaCO₃, 14.9 p.p.m.). The level of the salts should be largely controlled by the minerological characteristic of the ghanats.

Total hardness

This is the natural characteristic of water. According to the international norms, waters which contain up to 300 p.p.m. of total hardness are of medium quality, and water of acceptable quality has up to 500 p.p.m. of total hardness.

As shown in Table 12, in regard to the hardness of waters, the water in two stations--Shahabad (242 p.p.m.) and Mobarakabad (240 p.p.m.)--should be classified as of medium quality. Hosseinabad and Araj, with 307 and 312 p.p.m. of total hardness, respectively, represent an acceptable quality of water as far as hardness is concerned. The level of total hardness is highest in Araj, but the concentration of CaCO₃ is low. This suggests that the hardness parameters are being influenced largely by ions other than calcium.

Electrical conductivity

This is another parameter for estimating the total mineralization of water. According to the official standards

(Rodier, 1975), conductivity readings between the values of 333 and 666 s/cm are indicative of medium levels of mineralization. As shown in Table 12, Shahabad has the highest value for electrical conductivity (596); and in Mobarakabad it is less than in other ghanats. This agrees with the total hardness values, where Mobarakabad showed the least amount (240 p.p.m.). However, they all fall within the medium level of mineralization, according to electrical conductivity tests.

Temperature

Generally, water temperatures were slightly lower than ambient air temperatures (Table 13). In fact, the water temperature levels ranged from 13°C to 16°C in summer, and from 9°C to 14°C in winter for the ghanats. This is appropriate for the growth of planktonic organisms which were identified in the study areas. Many of the resident bacteria have an optimum growth temperature of 15°C.

The results of physical and chemical analyses indicated that the water in all stations is basic with a medium degree of mineralization. This would help to increase the growth of planktonic algae, which were identified in the ghanats. There is no significant pollution, however, because of chemical and physical ingredients.

TABLE 13. WATER AND AIR TEMPERATURE FOR EACH GHANAT, AUGUST 1978; FEBRUARY 1979.

STATION	SUMMER 1978		WINTER 1979	
	t _{air} °C	t _{water} °C	t _{air} °C	t _{water} °C
Mobarakabad	31	16	18	9
Shahabad	23	15	18	14
Hosseinabad	24	16	18	11
Araj	23	13	18	13

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Physical-chemical parameters

Physical and chemical tests were evaluated during the winter of 1979. Chemical tests included: dissolved gases, nitrates, hardness, and a few other inorganic compounds. Physical parameters were electrical conductivity and temperature.

(1) The DO content in all stations is at acceptable level.

(2) All CO₂ measurements correspond to the stations' DO content. The level of CO₂ was generally greatest in Araj. International norms indicate that the presence of CO₂ is not harmful to human health.

(3) Very minor variations occurred in pH value among the stations. Due to high levels of dissolved salts and pH, waters tend to be high in alkalinity. The pH level, however, for all stations was within the limits recommended for potable water.

(4) The water in two stations, Shahabad and Mobarakabad, should be classified with a medium quality for hardness. The two other stations had an acceptable quality of water hardness.

(5) According to the official standards, all stations fall within the medium level of mineralization in regard to electrical conductivity tests.

(6) The water temperature levels for the ghanats was sufficient for the growth of the planktonic organisms and many resident bacteria.

There is no significant pollution due to chemical and physical parameters.

Planktonic algae

(1) There were 47 genera of algae found in all four stations during the summer of 1978 and the winter of 1979. The planktonic population declined dramatically in winter.

(2) Chrysophyta was the dominant algae type isolated through summer and winter. The predominant genus, Cymbella, was similar for all stations.

(3) There were many algal genera in the ghanats which are tolerant of pollution, such as Chlorella, Oscillatoria, Microcystis, and different types of diatoms.

(4) Mean diversity (\bar{d}) and equitability (e) for the algae showed no significant level of water degradation and revealed nothing unusual.

Bacteria and yeasts/molds

(1) The number of total bacteria was higher in the summer period than in winter in the study areas. The level

of these bacteria was generally high for Mobarakabad in both seasons.

(2) Coliform bacteria for all stations were fewer than total bacterial count for both seasons. The dramatic drop in total bacterial count in the winter was not seen for the coliforms.

(3) Mobarakabad, with the highest level of total bacteria, has the next to lowest coliform count, and the lowest number of fecal coliforms. Perhaps water from this station is the safest for human consumption.

(4) Since there is a high density of total and fecal coliforms in Shahabad, this water source is probably unsafe for human use.

(5) The level of yeasts and molds is not as high as the number of total bacteria. Again, Mobarakabad had more yeasts and molds than the other stations.

Recommendations

The level of bacteria of the ghanats of metropolitan Tehran exceeds the safe limit of bacterial pollution. This could be accounted for by the inadequate sewer facilities in the city as well as the increasing human activity along a ghanat system.

The significance of water contamination with fecal coliforms is that their presence indicates the possibility of pathogenic forms which are the causative agents of many

intestinal diseases. The findings of this study suggest that further research will be required in order to see the ecological factors which result in contamination of this source of water.

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