# WATER QUALITY OF SPRINGS AND WELLS IN PROPERTIES LOCATED IN RURAL AND PERI-URBAN AREAS FROM BOTUCATU REGION, SP, BRAZIL

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## ABSTRACT

Water is an essential element to vegetal and animal life, and one of the most important vehicles of infectious diarrheal diseases. In this paper, the quality of water of 22 wells and six springs were analyzed in relation to its use, and in terms of the owner perception of the public health importance of water quality, aiming to determine the exposition level of the populations of risk studied. Three samples were collected from each water source for consecutive weeks. Samples were analyzed for total and thermotolerant (fecal) coliform bacteria, as well as for contamination with copper, phosphate and organochlorine content. Owners were interviewed in order to determine the type of treatment, and if samples have ever been collected and the water analyzed: 50% of the owners did not treat the water before use; 75% had little information about water quality and 86% did not know any waterborne diseases; as for use, 46% of the sources of water were for domestic use, irrigation and used as livestock / human drinking water. Results showed total coliform bacteria in 93% and thermotolerant coliform bacteria in 82% of water sources, associated with color and odor problems in the water. Copper and organochlorine were not detected; however, 53.6% of the water sources were contaminated with phosphates associated with the presence of particles. Water samples analyzed were considered to be unsafe for consumption and may pose an important public health risk.

**Key words**: Water quality, wells, springs, thermotolerant coliform bacteria, total coliform bacteria, phosphate.

# QUALIDADE DA ÁGUA DE NASCENTES E POÇOS EM PROPRIEDADES SITUADAS NAS ÁREAS PERI-URBANA E RURAL DA REGIÃO DE BOTUCATU, SP, BRASIL

## RESUMO

A água constitui elemento essencial à vida vegetal e animal, sendo também um dos mais importantes veículos de enfermidades diarréicas de natureza infecciosa. Neste trabalho, a qualidade da água de 28 fontes de água, 22 poços e seis minas, foi analisada quanto ao uso em relação a percepção da importância da qualidade da água pelo proprietário quanto à saúde pública, objetivando determinar o grau de exposição das populações de risco estudadas. Colheram-se três amostras de cada fonte, em semanas consecutivas. As amostras foram analisadas para coliformes totais e termotolerantes (fecais), e análises de contaminação com cobre, fosfato e organoclorado. Foram ainda realizadas entrevistas aos proprietários sobre tipo de tratamento, e se as amostras já haviam sido analisadas. 50% dos proprietários não

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faziam nenhum tipo de tratamento da água antes do seu uso; 75% tinham pouca noção sobre qualidade da água e 86% não tinham conhecimento de doenças de veiculação hídrica; 46% das fontes eram usadas para uso doméstico, para dessedentação humana e animal, e irrigação. Os resultados revelaram contaminação por coliformes totais em 93% e de coliformes termotolerantes em 82% das fontes de água, associado à presença de cor e odor na água. Não foram detectados cobre e organoclorado nas amostras; contudo, 53,6% das fontes estavam contaminadas com fosfatos, associada à presença de sujeira. Deste modo, as amostras de água utilizada nas propriedades foram consideradas impróprias para consumo e um importante fator de risco à saúde pública.

**Palavras-chave:** Qualidade da água, poços, minas, coliformes termotolerantes, coliformes totais, fosfato.

## CALIDAD DEL AGUA DE NACIENTES Y POZOS EN PROPIEDADES LOCALIZADAS EN LAS ÁREAS PERI-URBANA Y RURAL DE LA REGIÓN DE BOTUCATU, SP, BRASIL

## RESUMEN

El agua es un elemento esencial para la vida vegetal y animal, siendo también uno de los vehículos más importantes de enfermedades diarreicas de naturaleza infecciosa. En este trabajo, la calidad del agua de 28 fuentes de agua, 22 pozos y seis resortes, fue analizada cuanto al uso en relación a la percepción de la importancia de la calidad del agua por el propietario cuanto a la salud pública, objetivando determinar el grado de exposición de las poblaciones de riesgo estudiadas. Tres muestras de cada fuente fueron cosechadas en semanas consecutivas. Las muestras fueron analizadas para coliformes totales y termotolerantes (fecales), y análisis de contaminación con cobre, fosfato y organoclorado. Aún entrevistas fueron realizadas a los propietarios sobre el tipo de tratamiento, y si las muestras ya habían sido analizadas. 50% de los propietarios no hacían algún tipo de tratamiento del agua antes de usar la misma; 75% tenían poco conocimiento a respecto de la calidad del agua y 86% no tenían conocimiento de enfermedades de vehiculación hídrica; 46% de las fuentes eran usadas para el uso doméstico, para consumo humano y animal, y irrigación. Los resultados revelaron contaminación por coliformes totales en 93% y de coliformes termotolerantes en 82% de las fuentes de agua, asociado a la presencia de color y olor en el agua. No se detectaron cobre y organoclorados en las muestras; pero, 53,6% de las fuentes estaban contaminadas con fosfatos, asociada a la presencia de suciedades. Por lo tanto, las muestras de agua utilizadas en las propiedades fueron consideradas incorrectas para el consumo y un importante factor de riesgo para la salud pública.

**Palabras-clave:** Calidad del agua, pozos, resortes, coliformes termotolerantes, coliformes totales, fosfato.

## INTRODUCTION

Water is one of the most important vehicles of infectious diarrheal diseases. Waterborne diseases are caused by pathogenic microorganisms transmitted by fecal-oral route, by consuming either feces-polluted water or food contaminated by this water (1, 2, 3, 4).

Adequate harvesting and use of water, especially in rural and peri-urban areas are of fundamental importance. In rural areas, the main sources of water are shallow wells and springs. In these areas, the risk of outbreaks of waterborne diseases is high, mainly when wells are located near septic tanks and pastures (5).

Groundwater is largely responsible for the water supply in rural areas. In several regions, groundwater is not monitored or submitted to any treatment before use (6). The main sources of contamination of groundwater are generally associated with industrial and domestic discharges and runoff from sanitary landfills that contaminate aquifers with pathogenic microorganisms (7).

Coliform bacteria are considered to be indicators of fecal pollution in the evaluation of sanitary conditions of the water, and have been the focus of several recent studies (4, 8). Phosphate levels should be analyzed in areas where agricultural activities are practiced due to the use of chemical products in the plantation. High phosphate levels in superficial and groundwater may also be related to decomposition of organic material, discharge of industrial or domestic wastewater, residues of lixiviation of minerals, natural degradation processes, use of fertilizers and detergents, presence of animal excreta, residues of insecticides, herbicides, chemical fertilizers, and limestone, among other compounds (9, 10 ,11).

The objective of this study were to determine the quality of water in relation to its use by means of total and thermotolerant coliform counts and phosphate, copper and organochlorine content analysis, and to evaluate the owners perception of the importance of water quality in terms of public health.

## MATERIAL AND METHODS

Botucatu is a city located in the south central region (22°53’09’’S, 48°26’42’’O) of the state of São Paulo, Brazil, at 804 m of altitude, characterized by a high-altitude tropical climate. Botucatu is 235 Km away from the capital, São Paulo, and connected to it by two main highways, Rodovia Marechal Rondon and Rodovia Castelo Branco. According to the 2007 census, the city has 120,800 inhabitants (12). Botucatu is drained by the Rio Tietê basin to the north, and Rio Pardo basin to the south. Main soil types are arenito Botucatu and red latosol, and the soil profile is very deep and permeable. These characteristics are responsible for the deep location of the water table.

Random sampling without replacement involved 80 alternative sources of water (71 wells and 9 springs) with 90% acceptance range, 10% error and 95% significance level. Twenty-eight sources were selected by a draw: 22 wells and six springs (13), characterized and located by means of a GPS (Global Positioning System), kindly supplied by the Botucatu City Hall. Figure 1 shows the location of each water sources.

The owners of the respectively property water sources were interviewed and water samples were collected for analysis. Interviews were based on a questionnaire that focused on the characteristics of the sources of water and on the owner perception of the importance of water quality.

Three samples were collected from each source of water in three consecutive weeks. For bacteriological analysis, 300 mL were collected in sterile wide mouth flasks. For organochlorine analysis, 250 mL of water were collected in plastic flasks and sent to the *Centro de Assistência Toxicológica* (CEATOX), *Instituto de Biociências* (IB), UNESP, Botucatu Campus, SP. For the analysis of phosphate and copper content, 2 L and 1 L were respectively collected in plastic flasks and sent to the *Departamento de Química e Bioquímica* of the same *Instituto de Biociências*.

The Most Probable Number (MPN) of total and thermotolerant coliform bacteria were determined using the multiple tube technique and 100 mL of the sample: 10 mL of each sample were inoculated in five tubes containing double strength lactose broth and Durham tubes; 1 mL of each sample was inoculated in five tubes containing single strength lactose broth; 0,1 mL of each sample was inoculated in five tubes containing single strength lactose broth. All tubes were incubated at 35°C ± 2.0 and results were read after 24-48 hours. Tubes showing gas were used in the confirmation step to determine the presence of total and thermotolerant coliforms (14, 15).

Each culture that yielded positive results was transferred to tubes containing brilliant green bile lactose broth (BGBLB) and EC (*Escherichia coli*) broth. BGBLB tubes were incubated at 35°C ± 0.5 for 48 hours to confirm the presence of total coliform bacteria; positive tubes showed gas due to lactose fermentation. EC broth tubes were incubated in a water bath at 44.5°C ± 0.5 for 24 hours, and tubes positive for fecal coliform bacteria showed gas after incubation. Based on the positive results and using the MPN table (Hoskins' table), the MPN of thermotolerant and total coliforms.100 $mL^{-1}$ of the sample was determined and compared with official regulations (14).

The phosphate, copper and organochlorine pesticide contents were determined by Profa. Dra. Assunta Maria Marques da Silva, in the Laboratory of Chemistry, Department of Chemistry and Biochemistry, Institute of Biosciences, UNESP, Campus of Botucatu, SP. Phosphate content was determined using molybdenum blue spectrophotometric method (16), by the reaction of phosphate and ammonium molybdate. The condensation of phosphate and molybdate ions in acid solution will form ammonium phosphomolybdate complex that, by oxidation, produces blue color (molybdenum blue). The intensity of blue color is proportional of phosphate ions concentration in water sample and determined in a spectrophotometer. Copper content was determined by means of digestion to 2 mL in a digestor block. Organochlorine pesticide content was carried out by means of gas chromatography for aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide, DDT and lindane-2,4D (17).

According to Decree no. 518 from the Brazilian Ministry of Health, the presence of total coliform bacteria is acceptable, provided that *E. coli* and/or thermotolerant coliforms are absent in 100 mL of the sample (18). According to Resolution no. 357 from the National Environment Council (CONAMA, 03/17/2005), 0.025 $mg.L^{-1}$ of phosphate is the maximum acceptable value for a good quality of water (19).

As for the questionnaire, quantitative variables were analyzed by means of descriptive measures involving location and variability of the data. Relative and absolute frequencies were used in the categorized answers. Variables were compared by means of Mann-Whitney nonparametric test when there were two possible answers and Kruskal-Wallis when the number of categories was greater than two, at a 5% significance level (20).

## RESULTS AND DISCUSSION

Copper and organochlorine were not detected in the samples. Results of total and thermotolerant coliform bacteria counts, and phosphate content in the 28 sources of water studied are shown in Table 1 and Fig. 1. Medians were respectively equal to 42.3 and 7.7 $MPN.mL^{-1}$, and 0.031 $mg.L^{-1}$ and maximum values were equal to 240.0 and 240.0 $MPN.mL^{-1}$, and 0.152 $mg.L^{-1}$ (Table 1). These results are above than those determined by official Brazilian regulations.

According to Decree no. 518 of the Brazilian Ministry of Health, which determines the procedures and responsibilities related to the control, monitoring and quality standards of drinking water, thermotolerant coliforms should be absent in water destined to human consumption (18). Results obtained showed that around 93% of the sources of water analyzed were contaminated with total coliform bacteria and 82% by thermotolerant coliform bacteria, and were not safe for consumption.

Table 1. Total and thermotolerant coliform bacteria counts and phosphate levels in the 28 sources of water studied.

| Source | Total coliforms (MPN.100mL$^{-1}$) | | | Thermotolerant coliforms (MPN.100mL$^{-1}$) | | | Phosphate (mg.L$^{-1}$)* |
|---|---|---|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Sample 1 | Sample 2 | Sample 3 | |
| 1 | 23 | 17 | 240 | 13 | 0 | 240 | 0.028 |
| 2 | 7 | 130 | 130 | 2 | 0 | 130 | 0.070 |
| 3 | 22 | 8 | 4 | 11 | 0 | 4 | 0.111 |
| 4 | 17 | 0 | 13 | 0 | 0 | 13 | 0.152 |
| 5 | 30 | 4 | 4 | 0 | 4 | 4 | 0.068 |
| 6 | 22 | 2 | 4 | 0 | 2 | 4 | 0.021 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0.066 |
| 8 | 30 | 240 | 34 | 23 | 0 | 0 | 0.033 |
| 9 | 2 | 130 | 30 | 2 | 0 | 0 | 0.028 |
| 10 | 2 | 0 | 0 | 2 | 0 | 0 | 0.021 |
| 11 | 0 | 8 | 0 | 0 | 0 | 0 | 0.079 |
| 12 | 11 | 13 | 50 | 14 | 13 | 0 | 0.024 |
| 13 | 4 | 0 | 23 | 4 | 0 | 0 | 0.015 |
| 14 | 0 | 4 | 0 | 0 | 4 | 0 | 0.012 |
| 15 | 17 | 80 | 30 | 0 | 50 | 30 | 0.013 |
| 16 | 50 | 130 | 240 | 50 | 130 | 50 | 0.000 |
| 17 | 130 | 240 | 240 | 130 | 30 | 27 | 0.006 |
| 18 | 50 | 130 | 0 | 50 | 13 | 0 | 0.004 |
| 19 | 130 | 240 | 240 | 130 | 240 | 240 | 0.011 |
| 20 | 80 | 0 | 4 | 27 | 0 | 4 | 0.059 |
| 21 | 240 | 240 | 130 | 240 | 50 | 50 | 0.019 |
| 22 | 0 | 0 | 4 | 0 | 0 | 0 | 0.023 |
| 23 | 4 | 240 | 240 | 2 | 240 | 240 | 0.034 |
| 24 | 0 | 4 | 0 | 0 | 4 | 0 | 0.025 |
| 25 | 80 | 130 | 130 | 14 | 50 | 130 | 0.031 |
| 26 | 240 | 23 | 50 | 240 | 13 | 50 | 0.040 |
| 27 | 7 | 240 | 2 | 4 | 2 | 0 | 0.031 |
| 28 | 240 | 240 | 240 | 240 | 240 | 240 | 39 |

Legend: * mean phosphate levels of three samples; 1, 2, 3 - Rubião Jr.; 4, 5, 6 - Jd. Sta. Elisa; 7 - Jardim Tropical; 8, 9 - Recanto Árvore Grande; 10 - Vila Real; 11, 12, 13, 14, 15 - Recreio do Havaí; 16, 17 - Jardim Brasil; 18, 19, 20 - road to Vitoriana; 21 - Jardim Paraíso; 22 - Lageado; 23, 24 - Aracatu; 25 – Lageado; 26 - Jardim Eldorado; 27, 28 - Jardim Continental.

Similar results were obtained in the northeast region of the state of São Paulo by Amaral et al. (11), and in the state of Rio de Janeiro by Freitas et al. (7), who found that 96 to 100% of the samples collected from shallow wells in urban areas were contaminated by fecal coliform bacteria. This finding evidences the risk that untreated water poses to the health of the population.

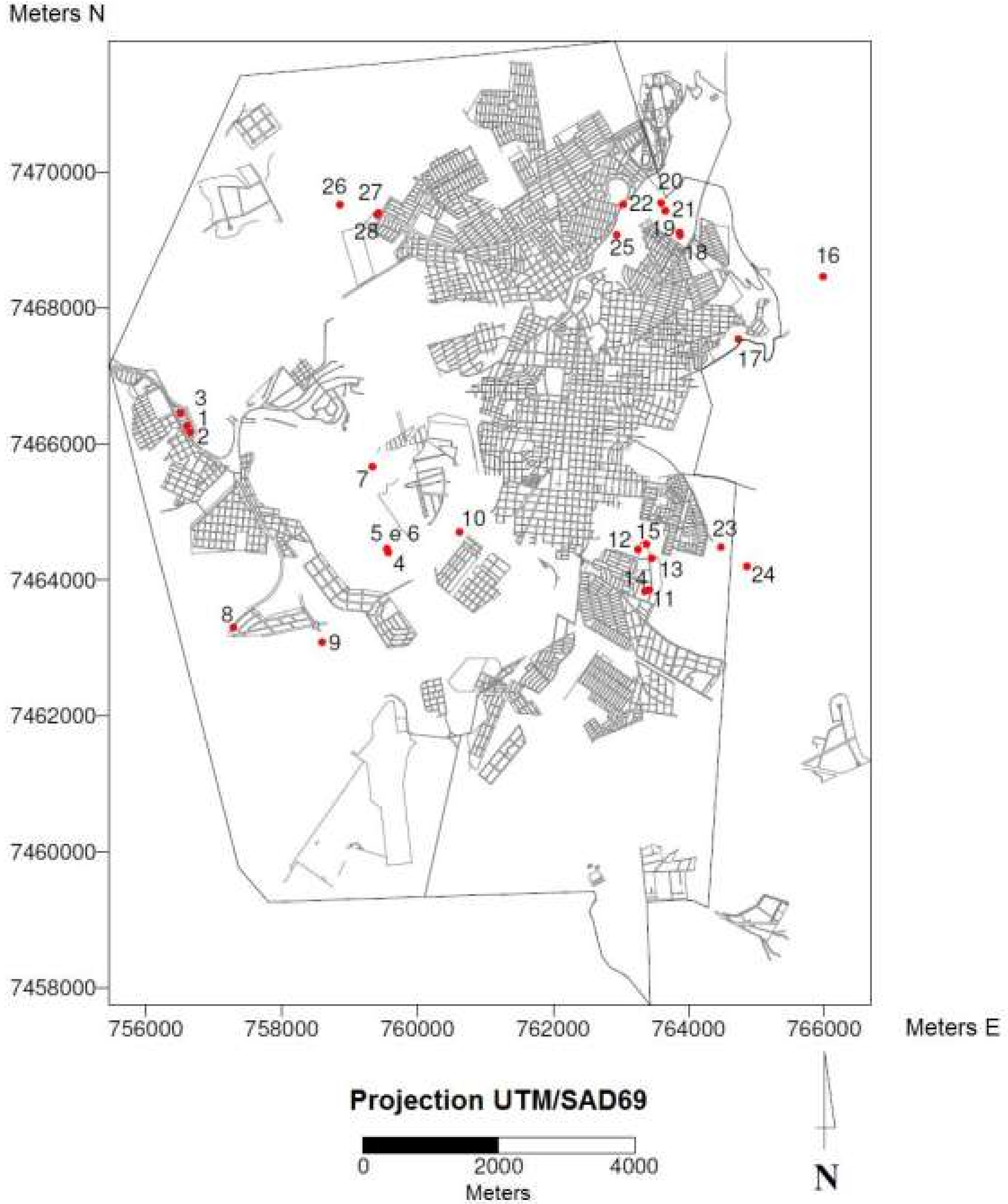


**Fig. 1.** Territorial map of Botucatu.

**Legend:** 1, 2, 3 - Rubião Jr.; 4, 5, 6 - Jardim Santa Elisa; 7 - Jardim Tropical; 8, 9 - Recanto Árvore Grande; 10 - Vila Real; 11, 12, 13, 14, 15 - Recreio do Havaí; 16, 17 - Jardim Brasil; 18, 19, 20 - road to Vitoriana; 21 - Jardim Paraíso; 22 - Lageado; 23, 24 - Aracatu; 25 – Lageado; 26 - Jardim Eldorado; 27, 28 - Jardim Continental

Phosphate analyses showed levels above the recommended threshold (19) of 0.025 $mg.L^{-1}$ in 15 (53.6%) of 28 sources of water. Fertilizers used in agricultural practices have high phosphorus content, and residues carried by rain waters may pollute rivers and lakes. Phosphates are also found in most detergents. Phosphate incidence may be a result of land occupation, mineral lixiviation, decomposition of organic material, domestic sewage or even animal excreta. In the present study, only eight sources of water (25%) showed phosphate levels that did not comply with the regulations (Fig. 2).

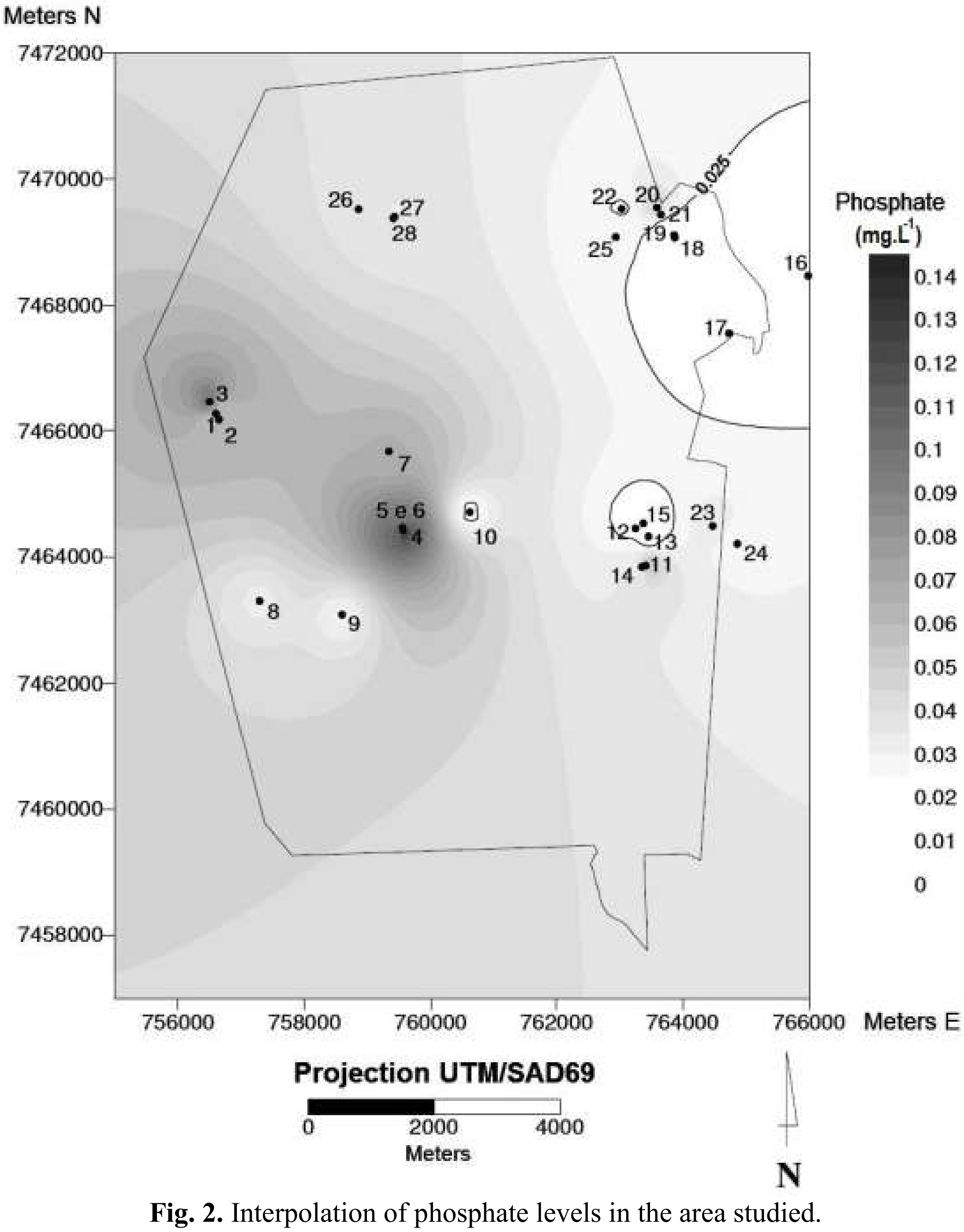


**Fig. 2.** Interpolation of phosphate levels in the area studied.

**Legend:** 1, 2, 3 - Rubião Jr.; 4, 5, 6 - Jardim Santa Elisa; 7 - Jardim Tropical; 8, 9 - Recanto Árvore Grande; 10 - Vila Real; 11, 12, 13, 14, 15 - Recreio do Havaí; 16, 17 - Jardim Brasil; 18, 19, 20 - road to Vitoriana; 21 - Jardim Paraíso; 22 - Lageado; 23, 24 - Aracatu; 25 – Lageado; 26 - Jardim Eldorado; 27, 28 - Jardim Continental. Thin black line: urban area; Thick black line: acceptable threshold for phosphate levels.

According to the questionnaires, most of the interviewees (75%) had no knowledge of water quality or waterborne diseases (86%) and did not treat the water with chlorine before consuming it (50%). However, water was filtered (physical treatment) by 46% of them. Garbage was burned by 51.8% of the interviewees and 48.2% used the public company pick up. Although garbage burning had a protecting effect ($P \leq 0.05$) in relation to the presence of total (M = 86.66 $MPN.mL^{-1}$) and thermotolerant (M = 44.49 $MPN.mL^{-1}$) coliform bacteria, the procedure was a risk factor ($P \leq 0.05$) for unacceptable phosphate levels (M=0.03 $mg.L^{-1}$), as shown in Table 2.

Table 2. Association between epidemiological variables of the questionnaire and results of the analyses. Botucatu, 2008.

| **Variable** | **Total coliforms** | | | | | **Thermotolerant coliforms** | | | | **Phosphate** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | $X$ | **M** | $d$ | $P$ | $X$ | **M** | $d$ | $P$ | $X$ | **M** | $D$ | $P$ |
| Type of source | | | | | | | | | | | | | |
| Flat well | 22 | 58.01 | 35.17 | 62.90 | NS | 30.16 | 6.33 | 49.66 | NS | 0.04 | 0.02 | 0.03 | NS |
| Spring | 6 | 121.35 | 137.33 | 99.56 | | 97.18 | 88.99 | 93.58 | | 0.05 | 0.03 | 0.05 | |
| Type of property | | | | | | | | | | | | | |
| House | 6 | 63.22 | 86.00 | 44.58 | | 23.84 | 1.52 | 33.83 | | 0.05 | 0.03 | 0.03 | |
| Mansion | 15 | 75.69 | 24.66 | 90.62 | NS | 50.14 | 9.00 | 77.18 | NS | 0.03 | 0.02 | 0.04 | NS |
| Small farm | 7 | 69.95 | 54.00 | 65.78 | | 50.18 | 10.33 | 63.73 | | 0.04 | 0.03 | 0.03 | |
| Form of captation | | | | | | | | | | | | | |
| Bucket | 7 | 102.28 | 101.33 | 56.07 | NS | 59.99 | 64.66 | 43.12 | NS | 0.04 | 0.03 | 0.03 | NS |
| Electric bomb | 21 | 61.35 | 24.66 | 78.71 | | 39.36 | 2.66 | 71.89 | | 0.04 | 0.02 | 0.03 | |
| Type of bathroom | | | | | | | | | | | | | |
| Septic tank | 21 | 66.82 | 28.00 | 76.48 | NS | 41.84 | 7.66 | 64.66 | NS | 0.04 | 0.03 | 0.03 | NS |
| Public water system | 6 | 81.29 | 71.50 | 79.42 | | 50.53 | 11.50 | 80.43 | | 0.04 | 0.03 | 0.03 | |
| Distance of the septic tanks | | | | | | | | | | | | | |
| Without septic tank | 7 | 76.84 | 71.50 | 76.47 | | 48.53 | 11.50 | 79.79 | | 0.03 | 0.02 | 0.02 | |
| Less than 15m | 3 | 37.99 | 11.33 | 55.07 | NS | 4.66 | 5.00 | 3.17 | NS | 0.05 | 0.03 | 0.04 | NS |
| Between 15 and 30m | 5 | 82.33 | 89.00 | 78.57 | | 50.39 | 44.00 | 48.15 | | 0.03 | 0.02 | 0.02 | |
| More than 30m | 13 | 72.68 | 35.16 | 82.00 | | 49.24 | 7.33 | 73.52 | | 0.05 | 0.03 | 0.04 | |
| Destiny of the trash | | | | | | | | | | | | | |
| Public collect | 13 | 42.30 | $24.66^{a}$ | 43.79 | S | 20.52 | $5.00^{a}$ | 34.21 | S | 0.04 | $0.03^{a}$ | 0.03 | S |
| Burning | 14 | 103.17 | $86.66^{b}$ | 87.54 | | 69.67 | $44.49^{b}$ | 80.74 | | 0.03 | $0.02^{b}$ | 0.03 | |
| Treatment of the water | | | | | | | | | | | | | |
| Without treatment | 14 | 76.64 | 71.50 | 69.54 | NS | 37.79 | 5.99 | 58.03 | NS | 0.04 | 0.03 | 0.04 | NS |
| Filtration | 13 | 62.92 | 24.66 | 84.46 | | 50.21 | 9.00 | 77.19 | | 0.04 | 0.03 | 0.03 | |
| Information about water quality | | | | | | | | | | | | | |
| Bad | 21 | 85.60 | 83.00 | 75.71 | NS | 51.00 | 21.00 | 67.73 | NS | 0.03 | 0.03 | 0.02 | NS |
| Good | 7 | 29.52 | 10.00 | 58.31 | | 25.05 | 2.66 | 59.83 | | 0.06 | 0.03 | 0.05 | |
| Knowledgement about water related diseases | | | | | | | | | | | | | |
| No | 24 | 74.04 | 51.16 | 76.44 | NS | 44.98 | 9.66 | 65.22 | NS | 0.04 | 0.02 | 0.03 | NS |
| Yes | 4 | 56.83 | 32.66 | 73.37 | | 41.74 | 2.83 | 79.30 | | 0.05 | 0.03 | 0.04 | |
| Source of water for irrigation | | | | | | | | | | | | | |
| None | 7 | 60.09 | 24.66 | 68.22 | | 35.86 | 2.00 | 61.60 | | 0.03 | 0.02 | 0.03 | |
| Well | 14 | 65.30 | 48.16 | 67.91 | NS | 40.29 | 15.66 | 57.54 | NS | 0.04 | 0.03 | 0.03 | NS |
| Spring | 5 | 90.95 | 10.00 | 120.08 | | 71.81 | 4.33 | 105.68 | | 0.05 | 0.04 | 0.05 | |
| Water reservoir | | | | | | | | | | | | | |
| Yes | 20 | 69.06 | 35.16 | 78.91 | NS | 46.15 | 5.83 | 73.79 | NS | 0.03 | 0.02 | 0.02 | NS |
| No | 8 | 77.87 | 91.16 | 68.45 | | 40.42 | 25.83 | 43.26 | | 0.06 | 0.03 | 0.05 | |
| Use of the source | | | | | | | | | | | | | |
| HD | 2 | 57.33 | 57.33 | 79.19 | | 32.38 | 32.38 | 45.65 | | 0.03 | 0.03 | 0.00 | |
| DOM+ HD+LD | 10 | 70.66 | 70.66 | 58.49 | NS | 48.09 | 26.50 | 55.67 | NS | 0.04 | 0.03 | 0.03 | NS |
| DOM+HD+LD+IR | 13 | 78.95 | 78.95 | 94.53 | | 53.16 | 10.33 | 81.77 | | 0.05 | 0.04 | 0.04 | |
| Water with color | | | | | | | | | | | | | |
| Yes | 5 | 110.26 | 93.33 | 78.95 | NS | 95.66 | $84.33^{b}$ | 88.27 | S | 0.04 | 0.04 | 0.02 | NS |
| No | 23 | 63.17 | 28.00 | 73.08 | | 33.40 | $4.33^{a}$ | 56.27 | | 0.04 | 0.03 | 0.04 | |
| Water with odor | | | | | | | | | | | | | |
| Yes | 4 | 131.66 | 98.83 | 72.51 | NS | 117.33 | $92.66^{b}$ | 85.20 | S | 0.04 | 0.04 | 0.02 | NS |
| No | 24 | 61.57 | 26.33 | 71.91 | | 32.38 | $4.66^{a}$ | 55.26 | | 0.04 | 0.02 | 0.03 | |
| Water with particles | | | | | | | | | | | | | |
| Yes | 4 | 111.16 | 96.66 | 95.05 | NS | 97.50 | 72.50 | 102.85 | NS | 0.06 | $0.05^{b}$ | 0.03 | S |
| No | 24 | 64.98 | 35.16 | 71.36 | | 35.68 | 5.99 | 55.91 | | 0.04 | $0.02^{a}$ | 0.03 | |

Legend: N = number of sources; $X$ = mean; M = median; $d$ = standard deviation; $P$ = $P$ value ($\alpha$ = 0.05); DOM = domestic use; HD = human drinking water; LD = livestock drinking water; IR = irrigation; S = significant; NS = non-significant. Statistic: different letters ($^{a,b}$) represents significant difference.

This lack of knowledge on water quality and waterborne diseases may be related to fact that this water was consumed for long periods without any problems. It may be added that because the water looked good, consumers had the impression it is pure. Results obtained corroborate this fact, for 96% of the interviewees had not shown any health problems in the 15 days prior to the interview, and around 86% of them said that the water did not have particles and/or color or odor problems. Color and odor problems in water were risk factors for the presence of thermotolerant coliforms ($P \leq 0.05$), with medians equal to 84.33 and 92.66 $MPN.mL^{-1}$, respectively, as shown in Table 2. The presence of particles in the water was considered to be a risk factor for high phosphate levels (0.05 $mg.L^{-1}$), and noncompliance with regulations ($P \leq 0.05$). As untreated well and spring water is popularly considered to be safe for consumption, consumers do not even disinfect it, as observed by Amaral et al. (11); disinfection would certainly minimize the risk of disease transmission. No other variable analyzed showed significant differences.

Geographic location of the sources associated with noncompliant coliform bacteria counts and phosphate levels should be a warning for the population against the use of the water from these sources. Although Fig. 3 shows that total coliform bacteria counts were variable, ranging from 0.5 $MPN.100mL^{-1}$ (sources 7, 10, 11 and 14) to 1.9 $MPN.100mL^{-1}$ (sources 16, 17, 18, 19, 27 and 28), the level of contamination is determined by the presence of thermotolerant coliforms. Fifteen of 27 (55.6%) sources (Fig. 4) distributed all over the city had detectable thermotolerant coliform concentrations, with high counts (150 $MPN.100mL^{-1}$) in five sources (18, 19, 23, 27 and 28). Once the presence of total coliform bacteria is acceptable, provided thermotolerant coliform bacteria and *E. coli* are absent, the sources of water analyzed pose a great public health risk. As for the levels of phosphate, most of the sources analyzed did not comply with the regulations (0.025 $mg.L^{-1}$) with acceptable concentrations in only 8/28 (28.6%) sources, one of which was located outside the urban area (Fig. 2). Two areas containing four sources (3, 4, 5 and 6) and almost 50% of the population of the region, showed phosphate levels ranging from 0.10 to 0.14 $mg.L^{-1}$. These results demonstrate that sanitary conditions of the water, together with cultural and popular habits, and the lack of sanitary education may lead to severe public health problems in the region.

Drainage of superficial water is the main factor affecting not only the microbiological quality of groundwater, but also the health of the consumers. Health risks are high in rural areas, mainly because of the possibility of bacterial contamination of the water of wells that are old, non-watertight and located near sources of pollution. Some basic conditions have to be considered when digging a shallow well: it should be located in the highest part of the property, at least 15 m away from sources of pollution, as far as possible and in the opposing direction of subterraneous drainage of known or probable sources of pollution; it should be covered with a lid; the wellhead should be at least 20 cm higher than ground level; there should be a 1 m curband around the wellhead (21). The lack of protective factors to preserve the quality of the water in most of the wells analyzed shows that there is a need to educate people on water quality preservation (11).

## CONCLUSIONS

The importance and the need to develop educational projects involving population living in these areas was corroborated by the results of this study, which showed careless harvesting and use of well and spring waters. Most of the water samples analyzed were found to be unsafe for consumption and a risk to the health of the people that use the sources, mainly when fecal coliform bacteria counts are considered. Therefore, the adoption of preventive measures in order to preserve these sources of water, and the treatment of those that are already affected are necessary to decrease the risk of waterborne diseases.

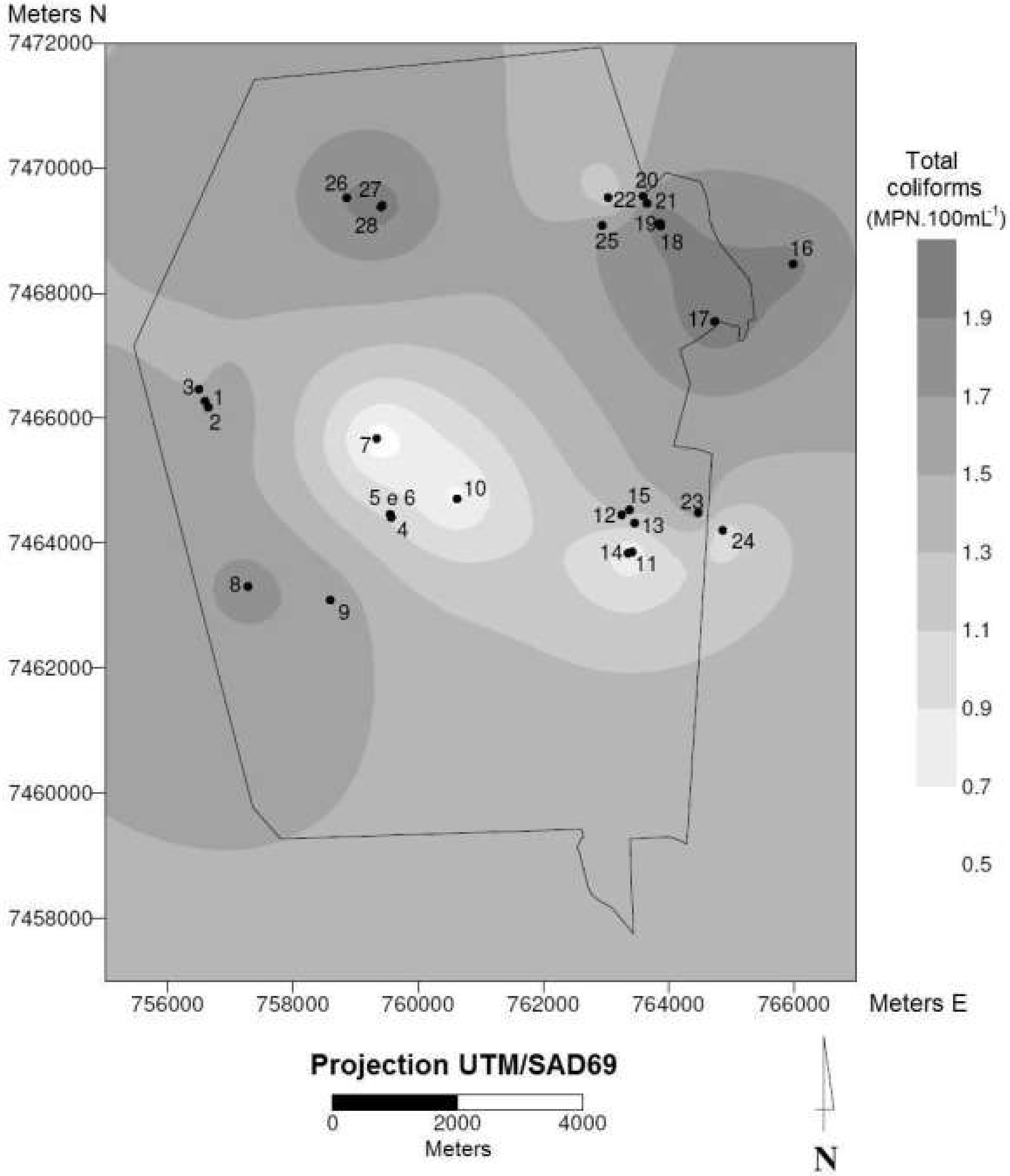


**Fig. 3.** Interpolation of total coliform counts in the area studied.

**Legend:** 1, 2, 3 - Rubião Jr.; 4, 5, 6 - Jardim Santa Elisa; 7 - Jardim Tropical; 8, 9 - Recanto Árvore Grande; 10 - Vila Real; 11, 12, 13, 14, 15 - Recreio do Havaí; 16, 17 - Jardim Brasil; 18, 19, 20 - road to Vitoriana; 21 - Jardim Paraíso; 22 - Lageado; 23, 24 - Aracatu; 25 – Lageado; 26 - Jardim Eldorado; 27, 28 - Jardim Continental. Thin black line: urban area.

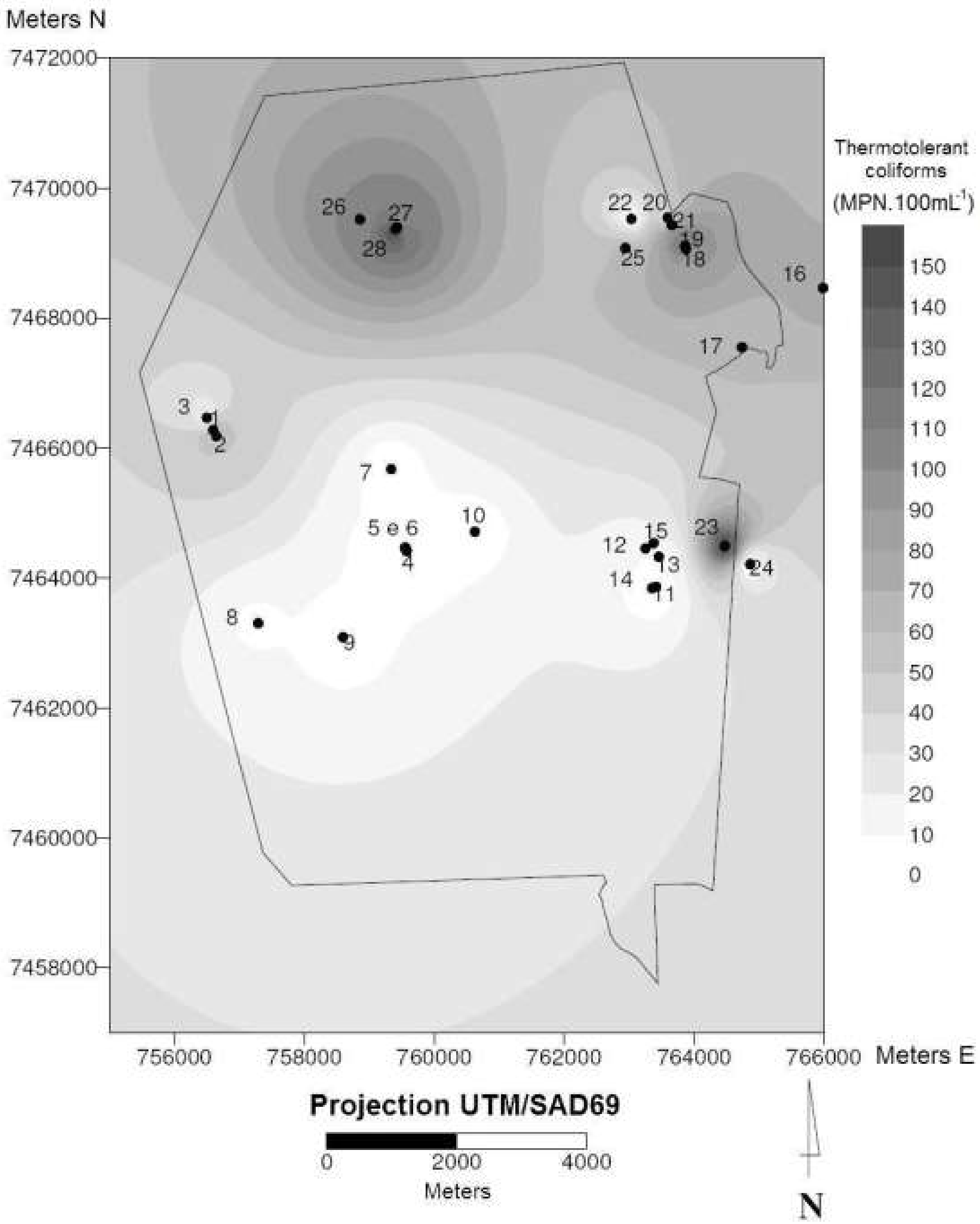


**Fig. 4.** Interpolation of thermotolerant coliform counts in the area studied.

**Legend:** 1, 2, 3 - Rubião Jr.; 4, 5, 6 - Jardim Santa Elisa; 7 - Jardim Tropical; 8, 9 - Recanto Árvore Grande; 10 - Vila Real; 11, 12, 13, 14, 15 - Recreio do Havaí; 16, 17 - Jardim Brasil; 18, 19, 20 - road to Vitoriana; 21 - Jardim Paraíso; 22 - Lageado; 23, 24 - Aracatu; 25 – Lageado; 26 - Jardim Eldorado; 27, 28 - Jardim Continental. Thin black line: urban area.

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