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Nitrite Concentration in Well Water from Poconé, Mato Grosso, and Its Relationship to Public Health in Rural Brazil

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Drinking water is a major avenue by which toxic substances and pathogens can enter the human body. In the industrial countries, continuous monitoring assures that this water does not contain excessive amounts of substances potentially dangerous to human health, but elsewhere in the world, undetected contamination still exists. A series of routine chemical analyses of the water in and near the Pantanal of Mato Grosso revealed that several wells located about 15 km south of the town of Poconé contained high concentrations of nitrite. It was therefore suspected that the inhabitants of this town might also have long been consuming nitrites on a regular basis.

Nitrite is known to cause respiratory deficiencies in aquatic animals (Almendras 1987, Ansari 1987, Liu and Kuo 1994) and human beings (Bradberry *et al.* 1994) by reacting with hemoglobin to form methemoglobin, thereby interfering with oxygen transport. Infant mortalities in the United States have been attributed to its presence in well water (Johnson and Kross 1990). The relationship between nitrite consumption and cancer is still controversial, but nitrosamines that can be formed by the reaction of nitrite with various proteins during digestion are known to be mutagenic and carcinogenic (Weng *et al* 1992). In southern China, positive correlations between the amounts of volatile n-nitrosamines in salted fish and the occurrence of nasopharyngeal carcinomas have recently been reported (Zou *et al.* 1994). In our study, the quality of the drinking water, both from the city water authorities (SANEMAT) and private wells, was determined to see whether a health danger from excessive nitrite concentrations exists in rural Mato Grosso. The water from none of these wells had ever before been analyzed for nitrite.

MATERIALS AND METHODS

Poconé is located in the State of Mato Grosso at the northern edge of the enormous Pantanal wetland. All of the wells sampled were located in the town itself or on ranches in or near the Pantanal to the south within 20 km of the town. Information on the surface water has already been published (Heckman 1994, 1995).

Water was collected from the wells in plastic buckets and analyzed immediately for all reported properties and substances, except nitrate, which was determined

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within 12 hours in the laboratory. The samples contained no visible particulate matter and were therefore not filtered or treated in any way before the reagents were added. Color comparisons of filtered and unfiltered samples revealed no differences in the Hazan values, which were invariably near zero.

The nitrite concentration was determined by a visual chromatic comparison of the color intensity produced by the Griess Reaction. The chemicals and color standards were purchased from Merck, Darmstadt. The estimated maximum error was ±35% with a minimum detectable value of 0.005 mg/l. Nitrate was reduced to nitrite in the laboratory with metallic cadmium. Then total nitrite-N was determined photometrically after the Griess reaction, and the amount recorded in the field was subtracted from the result. The remainder was assumed to have been nitrate-N in the sample. All nitrite-N and nitrate-N values were converted to nitrite and nitrate for the tables. The reagents and spectrophotometer were purchased from Hach. The other analytical methods have been described in detail by Heckman (1994, 1995).

RESULTS AND DISCUSSION

Data from regular periodic analyses of the surface waters of the Pantanal as well as rivers near Poconé were obtained during an extensive study from July 1991 to January 1995. The data for surface water (Heckman 1994) reveal that only traces of nitrate and nitrite are present in the region, except during short periods in the dry seasons, when slightly higher concentrations appeared after mass mortalities of the aquatic biota. In contrast, concentrations of ammonium were low but detectable throughout most of the year and sometimes very high during the dry season. The results of the groundwater analyses reveal a completely different situation in the uppermost aquifer (Table 1). Ammonium is seldom present in large amounts, while nitrate is almost always one of the important anions and, at some locations, is present in large amounts. A relatively high nitrite concentration almost always accompanies elevated nitrate values.

Analyses of five of the six deep wells used by the municipal water works (SANEMAT) to obtain running water for distribution to the residents of the city revealed nitrite concentrations below the accurate detection limits of the test, 0.005 mg/l. The sixth well contained a trace slightly above this value, estimated from a visual color comparison to be about 0.007 mg/l (Table 2). SANEMAT also takes water from the Rio Bento Gomes, which it treats before distribution. The nitrite concentration was determined at the treatment center and found to be below the test limit as well. Furthermore, many analyses of the water from this river at points near Poconé confirmed that it seldom contains more than a trace of nitrite (Heckman 1994). While the SANEMAT wells have been drilled into aquifers deeper than 100 m, the backyard wells are generally wide cylindrical shafts fed by the uppermost layer of ground water, which is seldom more than 25 m deep, For reasons still to be determined, this aquifer in certain regions in and near Poconé seems to be contaminated with very large amounts of nitrate, nitrite, and choride. At nearby locations, the subsurface water contains only traces of these anions (Fig. 1). Its pH is often quite low, as well (Table 1). While seasonal changes in the concentrations of ions in the surface water of the Pantanal are

Table 1. The chemical characteristics of private wells analyzed in and near Poconé (Fig. 1) and known occurrences of cancer among the persons who had regularly used the water or who may have used it occasionally.*

Well No.	Date	Temp.	Cond.	Hardn.	pH	O_2	Cl^{1-}	Fe^{2+}	NH_4^{1+}	NO_2^{1-}	NO_3^{1-}	PO_4^{3-}	Cancer mortality?
1	Nov.18,1993	27.7	421	1.3	6.8	1.3	35	2.8	3	0.4		0.47	Yes
2	Nov.11,1993	26.5	186	0.7	7.5	3.7	7	0.2	0.4	0.2		0.09	?
3	Nov.11,1993	28.0	463	0.6	5.5	2.9	40	0.1	<0.01	0.2		<0.05	No
4	Feb.25,1993	33.1	564	0.8	4.2	1.5	40	0.8	<0.01	0.19		<0.05	No
4	July.11,1993	24.9	533	0.8	4.4	4.1	40	0.2	<0.01	0.12		<0.05	No
4	July 6,1994	25.6	408	0.4	4.9	2.7	30	<0.1	<0.01	0.17		<0.05	No
5	Nov.18,1993	27.7	229	0.6	6.2	1.7	20	0.2	0.7	0.15		<0.05	Yes
6	Oct.18,1993	27.5	361	0.8	5.7	3.3	40	1.6	0.02	0.12		0.09	Yes
7	Nov.18,1993	27.2	269	0.7	6.3	4.2	22	<0.1	0.05	0.12		<0.05	No
8	Oct.18,1993	-	230	0.4	5.6	1.7	45	<0.1	0.15	0.10		0.19	No
9	Nov. 8,1993	27.4	1325	2.0	7.3	0.9	80	0.1	8	0.10		9.3	No
10	Nov.18,1993	27.5	211	0.6	6.2	3.2	14	<0.1	0.20	0.10		<0.05	No
11	Mar.17,1994	29.8	286	1.1	5.7	1.3	27	0.1	0.04	0.10	72.5	0.25	Yes
12	Mar.17,1994	29.6	303	0.6	6.0	1.2	25	<0.1	1.0	0.10	48.1	0.40	Yes
13	Mar.24,1994	33.3	243	1.1	6.3	-	6	<0.1	0.01	0.10		0.47	No
14	Dec. 2,1993	28.2	189	0.4	5.6	2.8	14	<0.1	0.04	0.06		<0.05	No
15	Oct.18,1993	27.1	184	0.4	6.1	1.4	18	<0.1	0.20	0.05		0.06	?
16	Mar.21,1994	28.9	151	0.4	5.7	4.2	12	<0.1	<0.01	0.05	35.0	0.06	?
17	Nov.18,1993	27.4	264	0.8	6.2	3.2	20	<0.1	0.01	0.04		<0.05	No
18	Mar.17,1994	28.5	244	0.8	6.5	4.1	11	<0.1	<0.01	0.04	21.7	1.24	Yes
19	Mar.21,1994	29.7	340	1.0	6.7	4.7	18	<0.1	0.03	0.03	16.3	0.06	No
20	Mar.17,1994	29.5	297	0.4	5.2	1.3	35	<0.1	<0.01	0.03	75.7	<0.05	No
21	Oct.18,1993	27.1	232	0.5	6.1	2.5	40	2.0	0.02	0.03		0.47	Yes

Table 1, continued

Well No.	Date	Temp.	Cond.	Hardn.	pH	O_2	Cl^{1-}	Fe^{2+}	NH_4^{1+}	NO_2^{1-}	NO_3^{1-}	PO_4^{3-}	Cancer mortality?
22	Mar.14,1994	28.4	261	0.5	5.5	3.2	30	0.4	0.03	0.025	73.1	0.12	No
23	Mar.14,1994	28.6	265	0.6	5.2	3.4	25	0.1	<0.01	0.025	65.1	<0.05	No
24	Oct.18,1993	27.6	274	0.5	6.2	2.5	28	1.4	<0.01	0.020	-	<0.05	Yes
25	Mar.17,1994	30.1	255	0.4	5.5	1.4	35	<0.1	0.06	0.018	35.0	0.28	No
26	Mar.21,1994	28.1	320	1.0	6.6	4.7	16	<0.1	0.02	0.018	25.1	1.55	No
27	Mar.14,1994	29.8	268	0.4	5.4	1.8	40	0.3	<0.01	0.015	62.9	0.06	No
28	Dec. 2,1993	28.0	274	0.7	6.0	3.3	22	<0.1	<0.01	0.010	-	<0.05	No
29	Dec. 2,1993	28.5	158	0.4	5.6	2.9	11	0.2	<0.02	0.009	-	<0.05	No
30	Nov.11,1993	28.0	28	0.1	5.8	2.0	2	0.7	0.17	0.008	-	<0.05	No
31	Nov.11,1993	28.7	12	0.0	5.8	6.9	1	1.6	<0.01	0.007	-	<0.05	No
32	Nov.11,1993	30.9	18	0.0	-	3.9	1	1.6	<0.01	0.007	-	<0.05	No
33	Mar.21,1994	30.2	118	0.3	5.7	4.5	0	<0.1	<0.01	0.005	24.6	<0.05	No
34	Mar.21,1994	28.8	170	0.4	5.6	1.6	14	<0.1	<0.01	0.005	40.0	<0.05	No
35	Nov.11,1993	27.3	565	1.7	7.4	0.7	6	2.8	4.5	0.005	-	3.7	No
36	Nov.11,1993	29.0	76	0.2	5.8	1.9	6	0.1	0.01	<0.005	-	0.47	No
37	Oct.18,1993	29.1	222	1.1	7.2	2.5	21	<0.1	<0.01	<0.005	-	0.17	No
38	Nov.11,1993	29.5	22	<0.0	5.9	7.8	2	0.8	<0.01	<0.005	-	<0.05	No

*Well 4 was analyzed on three different dates. The water temperature (Temp.) is shown in °C; the electrical conductivity (Cond.), in μS/cm; total hardness (Hardn.) in mmol/l; and the rest of the parameters as concentrations in mg/l. The information on mortalities caused by cancer refers to the owners of the well, their immediate families, and other people who regularly used water from the well.

Table 2. Water quality parameters in the deep wells used by the municipal water works (SANEMAT) as sources of drinking water for the city and in the Rio Bento Gomes (Fig. 1).*

Well No.	II	III	V	AP	IX	X	Rio Bento Gomes
Depth (m)	75	180	150	180	150	c.150	surface
Temperature (°C)	29.3	30.4	29.0	31.7	30.9	30.8	29.6
Electrical conductivity (μS/cm)	156.6	218.0	87.5	133.3	117.1	238.0	95.1
pH	7.3	7.6	6.7	7.0	-	7.0	6.8
Total hardness (mmol/l)	0.7	0.8	0.3	0.8	0.5	1.0	0.2
O_2 (mg/l)	9.4	6.3	5.4	4.3	4.9	3.6	2.2
Cl^{1-} (mg/l)	2	2	2	1.5	1.5	4	6
Fe^{2+} (mg/l)	0.2	<0.1	0.15	<0.1	<0.1	<0.1	0.8
NH_4^{1+} (mg/l)	<0.01	<0.01	0.04	<0.01	0.01	0.01	0.07
NO_2^{1-} (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.005

*The water from wells 2 and 9 were analyzed on October 28, 1993; the remaining analyses were completed on October 21, 1993.

extremely great (Heckman 1995), analyses of the well water on the Fazenda Ypiranga, about 15 km south of Poconé during each of the four seasons revealed no significant differences (Table 1).

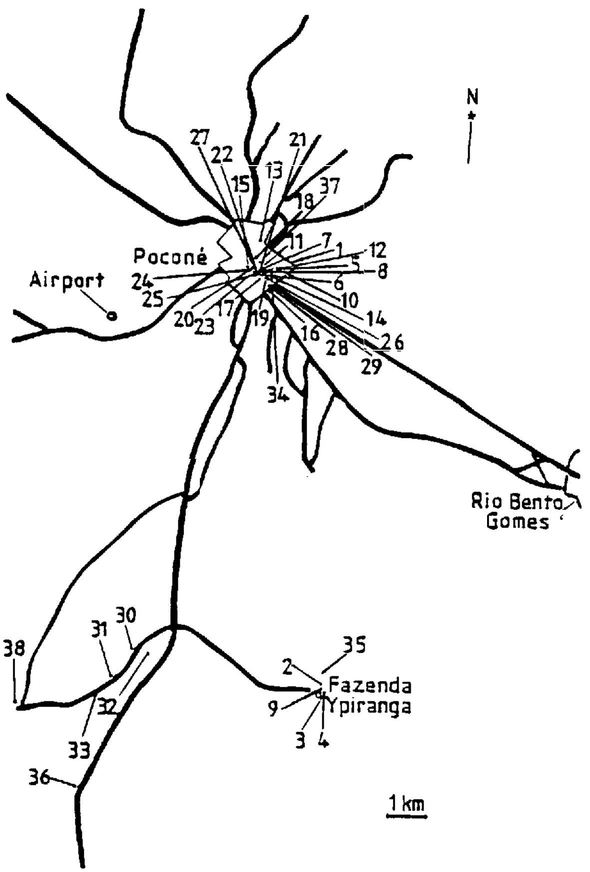

Figure 1. Map of Poconé located at 16° 15' S and 56° 37' S' W, the road system, and the locations of the wells listed in Table 1, which were assigned numbers to indicate their relative ranks according to the nitrite concentration. An obvious grouping of contaminated wells is evident on the Fazenda Ypiranga, and a second exists in Poconé, near the town center.

Danger from nitrite is not always indicated by its concentration alone. If much nitrate is present (Table 1), the possibility exists that some of it will be reduced to nitrite while passing through the digestive system. Even more likely is the conversion of nitrate to nitrite in the galvanized buckets that have been used for many years to collect and store the water. The combined amounts of nitrate and nitrite, as well as the low pH, make several wells in and near Poconé dangerous as water sources. The reaction of nitrite with proteins to form nitrosamines, which are mutagenic and induce neoplasms both in fishes (Bunton, 1989) and in man (Balaehandran, 1991; Saravanan and Nagarajan, 1991; Zou *et al.*, 1994), is favored by low pH. Drinking water in industrialized countries may occasionally be contaminated beyond the legal, safe limit, as found in the United States by Johnson and Kross (1990). In Germany, Schleyer and Kerndorff (1992) found that nearly 5% of the drinking water sources contained more nitrate than the legally permitted 50 mg/l. In contrast, 5 of the 13 well water samples analyzed in Poconé contained more than this value, and all 13 exceeded the average for German drinking water. The nitrite concentrations also surpass the average German values, many by a wide margin.

In summary, the general conditions in and near Poconé seem to be particularly conducive to the formation and assimilation of carcinogenic nitrosamines in persons consuming the well water for the following reasons: 1) the water of many wells contains high concentrations of nitrite; 2) the water in the same wells also contains high concentrations of nitrate, which is gradually reduced to nitrite in the galvanized pails that were used for many years to haul the water from the wells and store it for undetermined periods of time; 3) the pH of the water is usually in the acid range, reaching pH values as low as 5.2 in the city and 4.2 on one ranch, 4) the water is soft to extremely soft. This differs greatly from most nitrite-rich drinking water in the temperate zones, where the carcinogenic properties of nitrite are minimized in most cases by a slightly alkaline pH and the presence of calcium or other alkaline earth elements.

A comparison of the number of carcinomas detected in Poconé with the number reported from the entire state of Mato Grosso during the years 1989 through 1993 revealed no notable differences (Table 3). The organs in which the neoplasms developed are shown in Table 4. Estimations of the populations of Mato Grosso and Poconé in 1992 by the Instituto Brasileiro de Geografia e Estatistica in Cuiabá were 2,107,698 and 30,409, respectively. A comparison of the occurrence of malignancies in various organs also gave no indication of an effect from this nitrite. The organs that might well be subject to the most danger from contact with nitrosamines in drinking water, those in the digestive, lymph, and circulatory systems, are apparently less subject to cancer in Poconé than in other parts of the state. However, the statistics for the widely scattered rural population in Mato Grosso can scarcely be considered complete. Furthermore, there is no information about nitrite contamination of the drinking water elsewhere in the state, and apparently the water has never been analyzed for nitrite and nitrate.

Table 3. Deaths reportedly due to malignant neoplasms from 1989 through 1993

	Mato Grosso	Poconé
1989	515	12
1990	498	2
1991	492	6
1992	550	3
1993	617	4

Table 4. Primary locations of malignant neoplasms reported to cause deaths from 1989 through 1993. (The absolute numbers of cases and percentages of these cases in the total are shown.)

	Mato Grosso		Poconé	
Lips, mouth, pharyn	84	3.1%	1	3.7%
Digestive system, peritoneum	900	33.7%	8	29.6%
Respiratory system, thorax	357	13.4%	2	7.4%
Connective tissue, skin, breast	197	7.4%	3	11.1%
Urinogenital system	489	18.3%	8	29.6%
Lymphatic, hematopoetic organs	429	16.0%	2	7.4%
Other organs	216	8.1%	3	11.1%
Total	267	100%	27	99.9%

Although attention is given to the bacterial counts of the drinking water in Mato Grosso, the concentrations of potentially hazardous chemicals are not determined at all. It is hoped that this paper will call attention to the need for better monitoring of the nitrite and nitrate concentrations of water used for drinking and cooking in rural Brazil.

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