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REGULAR ARTICLE

Variability of drinking water for pigs and poutry the southern region of Brazil over a twelve – month period.

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Autor contribution
VB: Conducted experiment and recorded the data, stored the experimental data, performed the formal analysis of the study, Participated in the review of the literature cited in the manuscript, contributed to writing the original version of the manuscript; ALC: Performed the formal analysis of the study, participated in the review of the literature cited in the manuscript, contributed to writing the original version of the manuscript; MF: Formulated the research hypothesis, performed the formal analysis of the study, contributed to writing the original version of the manuscript, reviewed the manuscript before submission, supervised/led the research; LMS/DC/LS: Participated in the review of the literature cited in the manuscript, reviewed the manuscript before submission; CAK: Participated in the review of the literature cited in the manuscript; FR/DM/JM/MC: Conducted experiments and recorded the data; NPPB: Participated in the review of the literature cited in the manuscript.

Abstract

The increase in global food demand has led to intensified production of pigs and poultry. In this context, water quality on farms needs to be monitored to ensure maximum production and animal welfare. This study aimed to evaluate the quality and variability of drinking water for animals over twelve months in properties in the Southern Region of Brazil. Physical, chemical, microbiological parameters, and the average rainfall index of nine water sources were observed. Variations in pH were noted among the evaluated water sources, as well as within the same source over monthly collections. A relationship between average rainfall and elevated iron levels was also demonstrated. Nitrate and nitrite levels exceeded Brazilian legislation at certain sampling points, posing risks to human and animal health. In 67.59% of samplings, total coliforms were present, and 59.26% showed the presence of *Escherichia coli*. The study highlighted the variability of water sources in the Southern Region of Brazil, reflecting the need for constant monitoring and treatment measures, such as water treatment stations, chlorination systems, and acidification in rural properties.

Keywords

pH; Iron; Water quality; Monthly samplings.

Introduction

The growing demand for animal protein has stimulated the expansion of swine and poultry farming activities in Brazil, particularly in the Southern Region. This region accounts for approximately 68% of pig slaughter and 46% of broiler production in Brazil (Tremea et al., 2020; Galvani et al., 2023). This increase has led to efforts for improved management and biosecurity conditions (Hachmann et al., 2013). Among the necessary biosecurity measures, water quality on farms is especially highlighted (Massoni et al., 2017).

Water plays a fundamental role in the physiology of swine and poultry (Meunier-Salaün et al., 2016), constituting about 80% of their body composition (Palhares, 2013). It is an important component of tissues, involved in biochemical reactions and joint lubrication (Meunier-Salaün et al., 2016). Animals must have access to sufficient quantities of potable water to ensure welfare, making it indispensable for maintaining productive indices (Nyachoti and Kiarie, 2010; Meunier-Salaün et al., 2016; Shaw et al., 2018). In fact, water is the most consumed nutrient by animals and can become a source of disease dissemination (Palhares and Kunz, 2011).

In parallel, swine and poultry farming generate large volumes of waste, which are typically used in fertigation (Nyachoti and Kiarie, 2010). These wastes contain nitrogen, phosphorus, potassium, calcium, sodium, magnesium, and other organic components, as well as pathogens that can interfere with water composition through soil leaching (Oliveira, 1993; Souza et al., 2009; Carboni et al., 2012; Tiecher, 2017). This emphasizes the need for constant monitoring of physical, chemical, and microbiological parameters of water (Palhares and Kunz, 2011; Pereira et al., 2009).

Considering the significant role of water on farms, this study aimed to evaluate the quality and variability of groundwater and surface water composition in the Southern Region of Brazil over a twelve-month period.

Materials and methods

Water samples were collected from nine rural properties raising swine and poultry in the Southern Region of Brazil. These included Bom Retiro do Sul (P1), Teutônia (P2), Westfália (P3), and Poço das Antas (P4) in Rio Grande do Sul; São João do Itaperiú (P5) and Planalto Alegre (P6) in Santa Catarina; and Céu Azul (P7, P8, and P9) in Paraná, as shown in

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Figure 1. Monthly collections were conducted at each site over twelve months, from August 2022 to July 2023. Information was also gathered about the water source (artesian well/subterranean or spring/surface), depth and drilling time of the artesian well, type of farming (swine or poultry), and the water's intended use (human and/or animal consumption).

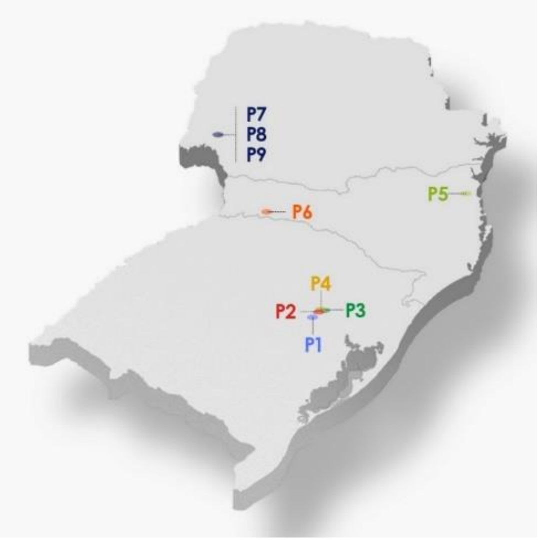

Figure 1. Map of the sampled area in this study, in the Southern Region of Brazil. The nine sampled points are highlighted.

Monthly, 1.4 liters of water were collected in specific containers from a faucet near each water source. Of this, 0.2 liters were designated for microbiological analyses (sterile packaging with $Na_2S_2O_3$ provided by the laboratory) and 1.2 liters for physicochemical analyses (new HDPE plastic containers, PE containers with HNO_3, and ionic PE containers). After sampling, the samples were kept refrigerated and processed within 24 hours. The study evaluated physicochemical and microbiological parameters, including pH (portable pH meter, Akso brand), free residual chlorine (portable chlorine meter, Akso brand), oxidation-reduction potential (ORP pocket meter, Akso brand), ambient temperature (digital thermometer, Incoterm brand), water temperature (portable pH meter, Akso brand), alkalinity (SMWW 2320 B), iron (SMWW 3500 Fe B), magnesium (SMWW 3500 Mg B), total dissolved solids (SMWW 2540 C), calcium (SMWW 3500-Ca B), total hardness (SMWW 2340 B and C), sulfate (EPA 300.1:1997), nitrite (SMWW 4500-NO2 B), nitrate (SMWW 4500-NO3 B), chloride (EPA 300.1:1997), *Salmonella* spp. (SMWW 9260 B), total coliforms, and *Escherichia coli* (SMWW 92623 B and 9221 C).

The results were compiled using Microsoft Excel (Microsoft Corporation, 2023) for the calculation of mean and standard deviation. During the study period, the monthly average of rainfall from the nearest meteorological station was also observed, with P1, P2, P3, and P4 using the Teutônia/RS station, P5 using the Chapecó/SC station, P6 using the Itajaí/SC station, and P7, P8, and P9 using the Foz do Iguaçu/PR station (INMET, 2023). The analysis results were correlated with the parameters established by Ordinance GM/MS No. 888, of May 4, 2021 (Brazil, 2021), which sets the standards for monitoring and surveillance of water quality for human consumption and the potability standards. This was necessary because waters were intended for both human and animal consumption at most collection points, this regulation was used as a reference.

Results and discussion

At 55.5% (5/9) of the collection points, the water originated from artesian wells, while 44.5% (4/9) came from springs. The depth of the artesian wells varied from 60 to 250 meters, with drilling times ranging from 2 to 17 years. In 77.8% (7/9) of the properties, swine were raised, and in 22.2% (2/9), poultry w raised. Additionally, in 77.8% (7/9) of the collection points, the water was intended for human and animal consumption, as shown in Table 1. Points P7, P8, and P9 are located on the same property but come from distinct sources.

According to the results compiled in Table 1, the water samples from P7 showed the highest average for pH and alkalinity throughout the study, which may correlate with the well depth. Table 2 highlights the average results over the twelve months of collection for some physicochemical parameters that can be easily measured on-site with portable equipment, along with environmental information.

The results in Table 2 represent a weighted average of the twelve analyses conducted throughout the evaluation period. The monthly average rainfall index varied from 128.30 ± 72.64 to 180.65 ± 133.65 mm (INMET, 2023). The average water temperature ranged from 19.48 ± 3.40 to 26.00 ± 1.84 °C, while the ambient temperature varied from 20.64 ± 5.44 to 22.58 ± 3.59 °C. The lowest water temperature was recorded in July 2023 at P3 (10.5 °C), and the highest temperature was in February 2023 at P6 (28.5 °C). Swine prefer to drink water at temperatures around 18 to 22 °C (Souza et al., 2016), and poultry prefer water between 10 and 14 °C (COBB, 2008). Throughout the study, the average water temperature did not meet these recommendations, which could affect water intake by the animals and necessitate management measures to ensure appropriate water temperatures (COBB, 2008).

Water samples were sampled before any treatment for potability, such as chlorination, resulting in zero free residual chlorine and an average ORP of 236 ± 83 mV. ORP represents the oxidation-reduction potential, indicating the capacity to inactivate microorganisms and oxidizing organic matter, serving as an indirect parameter water's microbiological quality. An ORP above 670 mV indicates bacterial deterioration in the water (Cano and Carrera, 2020; Zecchin et al., 2024). Therefore, ORP is a valuable tool for monitoring microbiological water quality in the field (Zecchin et al., 2024).

In this study, the average ORP remained below the recommended level, making the waters conducive to bacterial proliferation. The average ORP results in untreated raw water are consistent with the findings of Costa et al. (2024), who also observed ORP levels below 650 mV in raw water from rural properties raising swine and/or poultry in the Vale do Taquari region of Rio Grande do Sul, Brazil, which facilitates microbiological contamination.

The pH varied from 6.59 ± 0.28 to 10.18 ± 0.17. Greater variability in pH was observed at collection points P3 and P6, with P3 ranging from 7.10 to 8.40 (Figure 2) and P6 from 5.60 to 8.60 (Figure 3). Notably, pH in P7, P8, and P9—located within the same property, 600 meters apart—ranged from 6.59 ± 0.28 to 10.18 ± 0.17. This observed pH variation underscores the need for periodic water assessments. Many properties already use pH-regulating additives via drinking water to control and adjust pH, thereby improving performance and growth while reducing antibiotic use in production (Zecchin et al., 2024).

Table 1. Information related to the sampling of water collected over the twelve months.

Collection points	Water source	Well Depth	Drilling time	Type of farming	Water consumption
P1	Artesian well	136 meters	13 years	Swine	Human and animal
P2	Artesian well	60 meters	17 years	Swine	Human and animal
P3	Spring	NA	NA	Swine	Human and animal
P4	Spring	NA	NA	Swine	Animal
P5	Artesian well	100 meters	2 years	Poultry	Human and animal
P6	Spring	NA	NA	Poultry	Animal
P7	Artesian well	250 meters	2 years	Swine	Human and animal
P8	Spring	NA	NA	Swine	Human and animal
P9	Artesian well	230 meters	2 years	Swine	Human and animal

Note: NA: not applicable.

Table 2. Average results of pH, ORP, rainfall index, ambient temperature, and water temperature from the collection points over the evaluated period.

Points	pH	ORP (mV)	Rainfall index (mm)[1]	Water temperature (ºC)	Ambient temperature (ºC)
P1	9.29 ± 0.23	168 ± 45.45	128.30 ± 72.64	19.48 ± 3.40	21.45 ± 6.51
P2	7.44 ± 0.26	237 ± 54.35	128.30 ± 72.64	22.63 ± 2.50	22.03 ± 5.30
P3	7.23 ±0.80	249 ± 56.65	128.30 ± 72.64	19.78 ± 4.47	21.62 ± 5.39
P4	8.20 ± 0.48	205 ± 56.73	128.30 ± 72.64	20.48 ± 3.89	21.53 ± 6.31
P5	7.16 ± 0.51	317 ± 58.52	180.65 ± 133.65	22.12 ± 1.68	21.95 ± 2.47
P6	6.68 ± 0.90	394 ± 116.78	162.37 ± 79.93	20.42 ± 4.42	20.64 ± 5.44
P7	10.18 ± 0.17	110 ± 51.81	156.48 ± 107.43	26.00 ± 1.84	22.58 ± 3.59
P8	6.59 ± 0.28	249 ± 78.46	156.48 ± 107.43	20.94 ± 0.95	22.58 ± 3.59
P9	7.71 ± 0.32	192 ± 80.75	156.48 ± 107.43	22.28 ± 1.64	22.58 ± 3.59

[1] Date from the National Institute of Meteorology (INMET).

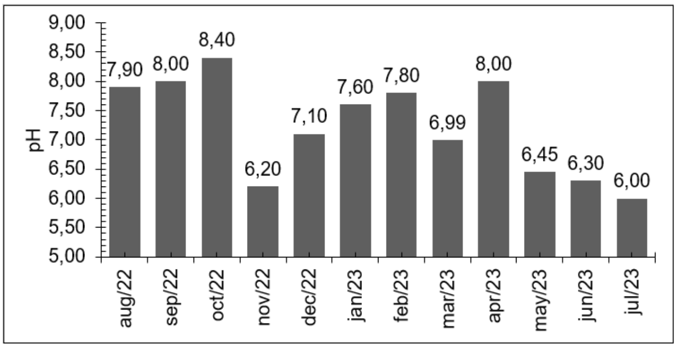

Figure 2. pH variation at the collection point P3, in the Westfália city, Rio Grande do Sul, over the months evaluated in the study.

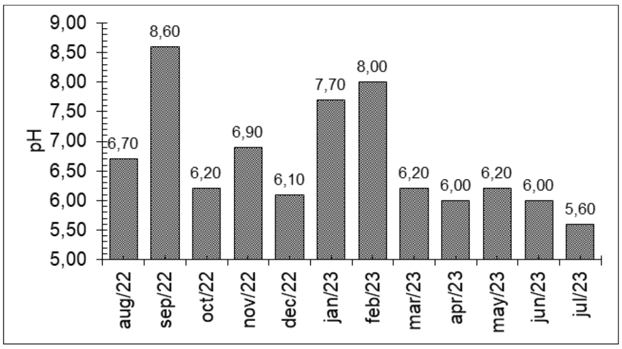

Figure 3. pH variation at the collection point P6, in the Planalto Alegre city, Santa Catarina, over the months evaluated in the study.

Table 3 presents the average results of the other physicochemical analyses of the water samples in this study. These results reflect the weighted average of the twelve analyses conducted.

Ordinance GM/MS No. 888/2021 (Brazil, 2021) does not establish a maximum allowable value for alkalinity. In this study, the average ranged from 22.08 ± 8.70 to 172.87 ± 29.24 mg/l. However, alkalinity is an interesting parameter as it reflects the capacity to neutralize acids, indicating the amount of ions in the water that neutralize hydrogen ions, which affects resistance to pH changes (Mendonça et al., 2019). Thus, alkalinity influences the use of acidity/pH regulators in drinking water, aiming to improve zootechnical indices (Nguyen et al., 2020). Levels above 80 mg/l impact the increased use of acidity regulators in drinking water (Bayer et al., 2024). Iron levels ranged from <0.05 ± 0.00 to 1.23 ± 1.40 mg/l, exceeding regulatory standards in some samplings. It was observed that increases in iron during certain months may be linked to higher rainfall in the previous month or the month of collection. This was evident at points P7, P8, and P9, which showed significant iron levels in November 2022, likely related to the substantial rainfall observed the previous month (October 2022 – 431.6 mm). Excess iron can alter the taste and odor of water and promote the growth of *Clostridium botulinum* in the intestines, potentially causing botulism in animals (Palhares and Kunz, 2011).

For total dissolved solids, no sample exceeded the regulatory standard, with variations from 50.14 ± 10.16 to 237.67 ± 55.20 mg/l. Total hardness ranged from 20.09 ± 2.31 to 125.93 ± 24.71 mg/l, and sulfates varied from 1.01 ± 0.30 to 30.92 ± 2.87 mg/l, both in compliance with the legislation (Brazil, 2021). Nitrate levels showed a variation from 0.14 ± 0.02 to 43.50 ± 9.90 mg/l, with some values exceeding the regulatory standards (Brazil, 2021). Regarding nitrites, there was a variation from <0.02 ± 0.00 to 0.33 ± 0.44 mg/l. Magnesium, calcium, and chlorides do not have maximum values established by the legislation (Brazil, 2021). However, it is known that excessive presence of these minerals can inhibit water consumption, potentially causing laxative effects and reducing productive indices (Palhares and Kunz, 2011). Regarding the iron, nitrate and nitrite parameters, collection points P6 in Santa Catarina and P7, P8, and P9 in the same property in Paraná showed values exceeding regulatory standards (Brazil, 2021). Points P6 and P8 consistently had elevated nitrate levels in all samplings, while P7 and P9 exhibited high nitrate values in most months. Specifically, P7 had elevated nitrate levels in November 2022, January 2023, February 2023, April 2023, May 2023, and July 2023. P9 recorded high nitrate levels in September 2022, October 2022, November 2022, December 2022, January 2023, February 2023, March 2023, April 2023, May 2023, June 2023, and July 2023.

Similarly, the study by Costa et al. (2024) also reported elevated nitrate levels at some samplings points. In August 2022, only point P9 exceeded the regulatory standard for nitrites (Brazil, 2021). This may be linked to excessive use of natural or synthetic fertilizers, which causes nitrogen accumulation in the soil in the form of nitrates that easily leach and contaminate groundwater and, consequently, underground water sources. Most available water treatment methods are unable to remove nitrates and nitrites (Tiecher, 2017), raising concerns since consumption of water with excess levels can lead to methemoglobinemia, decreased thyroid function and lowered blood pressure (Bayer et al., 2024; Costa et al., 2024).

Bacteria belonging to the total coliform group originate from the gastrointestinal tracts of animals and humans, including *Escherichia coli*, which causes diarrhea and infections in animals (Costa et al., 2024). The presence of *Escherichia coli* indicates fecal contamination in water (Libânio, 2010; Macedo et al., 2021). Water becomes a vehicle for disease transmission, highlighting the need to monitor the microbiological quality of drinking water for animals to ensure productivity and welfare in livestock (Lenz and Neves, 2023).

There is limited information on the presence of *Salmonella* spp. in groundwater. Its presence is believed to be influenced by temperature, chemical composition of the water, solar radiation, and the transport of the microorganism (Levantesi et al., 2012). In the present study, none of the evaluated collection points showed contamination by *Salmonella* spp. However, water samples were contaminated by total coliforms and *Escherichia coli*, as represented in Tables 4 and 5.

In this study, 67.59% (73/108) of the samples showed the presence of total coliforms, and 59.26% (64/108) showed *Escherichia coli*. These results corroborate the findings of Bortoli et al. (2018), who documented microbiological contamination of drinking water for humans and animals on dairy farms in Vale do Taquari, Rio Grande do Sul, Brazil. Bortoli et al. (2018) observed 96.15% contamination by total coliforms in animal drinking water samples, 62.5% in human drinking water, and 31.7% of human drinking water contained *Escherichia coli*. This reinforces the need for the implementation of chlorination processes on farms to ensure the elimination of pathogenic microorganisms from water. This would make it safe for consumption, reduce the incidence of diseases, and optimize productivity levels (Padilha et al., 2013). Chlorine, when in contact with water, forms hypochlorous acid, a strong biocide with significant disinfection power, and hypochlorite ion, a weaker biocide with less effectiveness (França and Santos, 2019). Chlorine is very efficient in disinfecting water; however, its effectiveness is influenced by the water's pH. At pH levels above 7.0, the biocidal action tends to diminish. Therefore, in certain situations, acidifying the water in conjunction with chlorination becomes essential for eliminating microbial contamination (Costa et al., 2024).

Conclusions

The study highlighted the variability of water sources in the South Region of Brazil, particularly regarding to pH, iron, nitrates, nitrites and microbial contamination. This emphasizes the need for regular water evaluations, especially during zootechnical and sanitary challenges. The water can be a vector for disease, compromising the human and animal health. There is also a need to treat water to ensure its potability. Numerous water treatment solutions are available, such as water treatment plants (WTPs), chlorination systems, and acidification. WTPs remove effectively organic and mineral impurities like iron and zinc, but they do not eliminate nitrates and nitrites. This fact reinforces the need for greater awareness about the use of organic and inorganic fertilizers in agriculture. Chlorination is essential for eliminating contamination, and in certain cases, chlorine should be combined with pH regulators to adjust pH and enhance chlorine effectiveness.

Table 3. Average results of the physicochemical analyses from the nine collection points over the twelve months of analysis.

Points	Alkalinity (mg/l)	Iron (mg/l)	Magnesium (mg/l)	Total dissolved solids (mg/l)	Calcium (mg/l)	Total hardness (mg/l)	Sulfate (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Chloride (mg/l)
Standard[1]	Standard not established	Max. 0.3	Standard not established	Max. 500	Standard not established	Max. 300	Max. 250	Max. 10	Max. 1	Max. 250
P1	98.13 ± 19.18	<0.05 ± 0.00	1.46 ± 0.22	149.07 ± 16.86	5.64 ± 0.57	20.09 ± 2.31	30.92 ± 2.87	0.14 ± 0.02	<0.02 ± 0.00	5.62 ± 0.58
P2	121.66 ± 17.42	<0.05 ± 0.00	12.20 ± 1.66	157.07 ± 20.56	30.33 ± 8.39	125.93 ± 24.71	11.83 ± 2.15	4.81 ± 1.18	<0.02 ± 0.00	6.96 ± 1.89
P3	27.27 ± 36.80	0.09 ± 0.00	1.98 ± 0.96	51.85 ± 34.04	5.91 ± 3.92	22.92 ± 11.00	1.31 ± 0.19	3.32 ± 2.47	<0.02 ± 0.00	3.38 ± 1.69
P4	40.78 ± 9.56	0.09 ± 0.06	4.62 ± 1.05	50.14 ± 10.16	8.60 ± 1.90	40.52 ± 9.09	1.47 ± 0.18	1.03 ± 0.59	<0.02 ± 0.00	1.69 ± 0.17
P5	40.86 ± 14.27	0.03 ± 0.00	3.28 ± 0.83	119.00 ± 42.11	8.39 ± 3.31	25.83 ± 12.07	1.01 ± 0.30	0.89 ± 0.38	0.08 ± 0.00	3.68 ± 0.68
P6	28.51 ± 6.57	0.49 ± 0.43	28.92 ± 10.16	137.00 ± 75.65	25.97 ± 6.52	54.90 ± 11.87	15.52 ± 12.82	43.50 ± 9.90	0.27 ± 0.14	5.70 ± 5.07
P7	172.87 ± 29.24	0.53 ± 0.45	11.98 ± 14.61	237.67 ± 55.20	7.40 ± 11.24	18.47 ± 25.77	8.39 ± 4.94	11.61 ± 6.21	0.16 ± 0.06	2.48 ± 4.33
P8	22.08 ± 8.70	1.18 ± 1.64	26.05 ± 26.51	83.83 ± 63.92	19.44 ± 6.38	45.46 ± 30.70	8.29 ± 4.09	0.16 ± 0.10	8.29 ± 4.09	2.80 ± 4.08
P9	113.24 ± 7.72	1.23 ± 1.40	31.85 ± 14.83	173.50 ± 41.22	56.75 ± 14.29	88.83 ± 20.05	10.49 ± 8.00	17.96 ± 7.55	0.33 ± 0.44	6.85 ± 3.50

[1] BRASIL. Portaria GM/MS nº 888, de 4 de maio de 2021. Brasília: MINISTÉRIO DA SAÚDE, [2021].

Table 4. Results of the analyses from the collection points for Total Coliforms (CFU/ml) and *Escherichia coli* (CFU/ml), respectively.

Points	Aug/22	Sep/22	Oct/22	Nov/22	Dec/22	Jan/23	Feb/23	Mar/23	Apr/23	May/23	Jun/23	Jul/23
P1	-/-	-/-	-/-	+/-	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+
P2	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+
P3	+/+	+/-	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+
P4	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+	+/+
P5	-/-	+/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
P6	+/-	-/-	+/+	+/-	+/+	+/+	-/-	+/+	+/-	+/+	+/+	+/+
P7	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	+/+	+/+	-/-
P8	+/+	+/+	+/+	-/-	+/+	+/+	+/+	+/+	-/-	+/+	+/+	+/+
P9	+	-	+	+	-	-	-	-	-	+/+	+	-

"-" Absence; "+" Presence.

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