Drinking water and rural schools in the Western Amazon: an environmental intervention study

Maura Regina Ribeiro [1] , **Luiz Carlos de Abreu** [1, 2] , **Gabriel Zorello Laporta** [Corresp. 1, 3]

[1] Setor de Pós-graduação, Pesquisa e Inovação, Centro Universitário FMABC, Santo André, SP, Brazil
[2] Department of Environmental Health, Harvard T H Chan School of Public Health, Boston, MA, USA
[3] Centro de Engenharia, Modelagem e Ciências Sociais Aplicadas, Universidade Federal do ABC, Santo André, SP, Brazil

Corresponding Author: Gabriel Zorello Laporta
Email address: gabriel.laporta@fmabc.br

Although water and sanitation are considered as a human right, about three out of ten people (2.1 billion) do not have access to safe drinking water. In 2016, 5.6 million students were enrolled in the 33.9% of Brazilian schools located in rural areas. Only 72% of them have a public water supply network. Herein, we proposed to evaluate the effectiveness of environmental intervention for water treatment in rural schools of the Western Amazonia. The study is characterized by an experimental design with environmental intervention for the treatment of water for human consumption, through the installation of a simplified chlorinator, in 20 public schools in the rural area of Rio Branco municipality, Acre state. Before the intervention, the results revealed 20% (n = 4), 100% (n = 20) and 70% (n = 14) of schools having water outside the potability standards for Turbidity, Faecal coliforms, and *Escherichia coli*, respectively. There was no significant difference in the turbidity results after the intervention (p = 0.71). On the other hand, there was a very significant difference in the results of Faecal coliforms and *Escherichia coli* after the intervention (p<0.001). The actions carried out in this intervention have considerably improved schools water quality, thus decreasing children’s health vulnerability due to inadequate water provided to the school community in the rural area. The activities such as training, educational lectures, installation of equipment, supply of materials and supplies (65% calcium hypochlorite, and reagents) were fundamental to obtain the results.

Article

Drinking water and rural schools in the Western Amazon: an environmental intervention study

Maura Regina Ribeiro[1], Luiz Carlos de Abreu[1,2], Gabriel Zorello Laporta[1,3*]
[1] Setor de Pós-Graduação, Pesquisa e Inovação, Centro Universitário FMABC, Santo André, SP, Brazil
[2] Department of Environmental Health, Harvard T H Chan School of Public Health, Boston, MA, USA
[3] Centro de Engenharia, Modelagem e Ciências Sociais Aplicadas, Universidade Federal do ABC, Santo André, SP, Brazil
*Corresponding author: GZL; **gabriel.laporta@fmabc.br**

Abstract

Although water and sanitation are considered as a human rights, about three out of ten people (2.1 billion) do not have access to safe drinking water. In 2016, 5.6 million students were enrolled in the 33.9% of Brazilian schools located in rural areas. Only 72% of them have a public water supply network. Herein, we proposed to evaluate the effectiveness of environmental intervention for water treatment in rural schools of the Western Amazonia. The study is characterized by an experimental design with environmental intervention for the treatment of water for human consumption, through the installation of a simplified chlorinator, in 20 public schools in the rural area of Rio Branco municipality, Acre state. Before the intervention, the results revealed 20% (n = 4), 100% (n = 20) and 70% (n = 14) of schools having water outside the potability standards for Turbidity, Faecal coliforms, and *Escherichia coli*, respectively. There was no significant difference in the turbidity results after the intervention (p = 0.71). On the other hand, there was a very significant difference in the results of Faecal coliforms and *Escherichia coli* after the intervention (p<0.001). The actions carried out in this intervention have considerably improved schools water quality, thus decreasing children's health vulnerability due to inadequate water provided to the school community in the rural area. The activities such as training, educational lectures, installation of equipment, supply of materials and supplies (65% calcium hypochlorite, and reagents) were fundamental to obtain the results.

Introduction

Depriving people of access to safe drinking water denies them the right to life[1]. Although water and sanitation are considered as a human right and a condition for human health, dignity, economic development and social well-being[2], worldly about three out of ten people (2.1 billion) do not have access to safe drinking water and six out of ten (4.5 billion) worldwide lack adequate sanitation[3].

The need for access to drinking water and sanitation is a public health issue[4], since its unavailability contributes to higher incidence of diseases such as diarrhea, cholera, hepatitis A and typhoid fever, among others[3].

In the year of 2016, 5.6 million students were enrolled in the 33.9% of Brazilian schools located in rural areas, with only 72% having a public water supply network[5].

As most rural population remains living adverse conditions and deprived of drinking water due to the lack of all the services, infrastructures and operational facilities, added to the geographic distance in the Amazon region, this intervention proposed the use of social technology with the main objective of social inclusion, and economic and environmental sustainability, aiming at an effective solution for the treatment of water for human consumption in rural schools in the city of Rio Branco (AC), since the Unified Health System (SUS) policy recognizes sanitation as a central role in improving the health conditions of the population.

Methods

Study design

The study is characterized by a pre-experimental design with environmental intervention for the treatment of water for human consumption, through the installation of a simplified chlorinator, in 20 public schools in the rural area of Rio Branco, AC. The steps involved in the present study were represented in infographic (Fig. 1).

Study area and studied population

The study was carried out in the rural area of the municipality of Rio Branco, located in the extreme southwest of the North Region, in the Brazilian Amazon (Table 1, Fig. 2). With a population estimated in 2016 of approximately 377,057 inhabitants, the municipality has an area of 8,835.52 km^2. The population living in rural areas in 2010 according to the Demographic Census is 27,493[6].

Environmental intervention: chlorinator

The simplified chlorinator is a social technology recommended by the Brazilian Agricultural Research Corporation (EMBRAPA) of São Carlos, SP, as a domestic method of disinfection of water in rural areas and with the purpose of facilitating the process of insertion of chlorine into water reservoirs (boxes of water), made with 25 mm welded PVC tubes, 3/4 *in* ball register, ¾ *in* male adapter threaded PVC, 25 × 3/4 *in* adapter, ½ *in* garden faucet, 25 × ½ *in* tube T-form connections, 60 × 25 *in*, glue and sandpaper, which were installed between the water intake port and the reservoir system.

Sampling drinking water in rural schools

In each school, 300 mL water samples were collected before and after reserving (canopy tap), with 100 mL for microbiological analysis and 200 mL for organoleptic tests. For post-intervention water samples, sterile plastic sachets containing sodium thiosulfate pellets were used for the neutralization of the chlorine present in the sample. The samples were then placed in a sterile box containing ice and transported to the Central Analysis Laboratory (LACEN) of the State Health Department (SESACRE).

Prior to each water collection, some procedures were adopted for the purpose of preserving the samples, among them cleaning of taps with 70% alcohol, washing and asepsis of hands with soap and 70% alcohol, enumeration of sterile plastic bags, flow of the tap water for 2 to 3 min to avoid the presence of accumulated residues in the inner part of the tubing and filling of the bag until three-quarters full for homogenization of its contents.

For organoleptic analysis, the nephelometric method recommended by the Standard Methods for Examination of Water and Wastewater (SMEWW), 21st Ed. 2130B, expressed in nephelometric units of turbidity (UNT) was adopted. For the microbiological analysis, the chromogenic/enzymatic substrate method was used, also recommended by the SMEWW, 21st Ed. 9223B, using a Colilert test kit and incubating the samples prepared in Digital model (Q-316-M5) bacteriological culture at 35 °C for 24 h.

Water parameters

The following parameters were analyzed: microbiological (total coliforms and *Escherichia coli*) and organoleptic (turbidity), in which significant associations were sought in the outcome after the intervention through water analysis, in order to evaluate the efficiency of the treatment.

The maximum permitted values (VMP) established by Ordinance MS No. 2914/2011 for the parameters *E. coli* and total coliforms are absence in 100 mL, the former being an indicator of fecal contamination and the second an indicator of treatment efficiency. For turbidity the VMP is 5.0 units of turbidity (uT).

Water chlorination

The chlorination of the water was done with granulated calcium hypochlorite (65%), diluted with water in a plastic container and immediately added to the simplified chlorinator installed in each school, at a dosage of one teaspoon per 1,000 L of water. For the monitoring of free residual chlorine (CRL), a HANNA brand portable Colorimeter Checker was distributed to each school. This instrument displays the free chlorine concentration in ppm (parts per million) and the result must be between 0.20 mg/L (minimum) and 2.0 mg/L (maximum), according to MS Ordinance No. 2914/2011.

Data analysis

For statistical analysis, we applied the Fisher's exact test for count data in the R programming environment v. 3.2.2, in order to associate the two nominal qualitative variables: 1, water potability (satisfactory, unsatisfactory); 2, intervention status (before, after intervention). A significance level equals 0.05 was considered in the hypothesis testing.

Results

This intervention study was motivated due to (by) the lack of water treatment offered in 65 schools located in the rural area of the city of Rio Branco, confirmed after water analysis. In this way, the intervention predicted the need for water treatment. In total, 20 schools were invited to participate in the intervention, 12 of the state administration (1,986 students) and eight of the municipal administration (960 students), comprising 2,946 nursery, elementary, and middle school children and staff, aged between 3 and 60 years old.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26475v1 | CC BY 4.0 Open Access | rec: 31 Jan 2018, publ: 31 Jan 2018

Of the water supply sources used by the educational establishments, 45% (N = 9) capture water from the Amazonas-Caçimbão well, 35% (N = 7) from an artesian well, 5% (N = 1) by water truck and 15% (N = 3) have mixed sources of supply, according to water availability and climatic conditions. The abstraction of the water by underground and superficial wells is made by electric pump and occurs as there is no public water supply system.

It was verified that all sources of groundwater abstraction were constructed in disagreement with the technical criteria of the Brazilian standards (ABNT) and without the permission of public bodies. In addition, the location of the wells did not take into consideration the possible risks of contamination by existing outbreaks, such as the minimum distance from the sanitary sewage system to wells, the presence of animals, residues, land used for agriculture and small, medium and large animals.

Only 10% (N = 2) of the schools treat the water after water collection. Aiming at the elimination of pathogenic microorganisms, the chemical agent used is 2.5% sodium hypochlorite solution, provided by the Ministry of Health (MS) and available in public health facilities in the city of Rio Branco. Another 90% (N = 18) do not perform any treatment, which makes water a disease-transmitting vehicle. However, 60% (N = 12) provide industrial, filtered water troughs that are directly linked to the school's water reserve system.

After inquiries directed to the principals of the schools, it was realized that water analysis had never been carried out, and those schools that are supplied by water trucks also did not require reports of the suppliers' water analysis.

There was no significant difference in the turbidity result before and after the intervention ($p = 0.071$) (Fig 3). Nonetheless, the results found for total coliforms showed that 75% of the 20 samples analyzed were in compliance with MS Ordinance No. 2914/2011, which is absence in

100 mL at the time of treatment. There was a very significant difference in the total coliform result before and after the intervention ($p = < 0.001$) (Fig. 4). Additionally, 100% (N = 20) of the samples were in compliance with Ordinance MS No. 2914/2011 for the *E. coli* parameter. There was a very significant difference in the *E. coli* result before and after the intervention ($p = < 0.001$) (Fig 5).

During the environmental health educational intervention process in each school, educational lectures were designed to present to the students, teachers, and service and school support professionals the objectives of the project, results of the analysis of the samples of water collected before the intervention, the chlorine installation process and its handling, and the apparatus for measurement of free residual chlorine and its handling, in addition to information about waterborne diseases. The approaches allowed for open discussions involving reflective thinking on personal health and hygiene issues, the role of water quality in health and disease, sanitation of reservoirs and protection of water sources, as well as water treatment, in order to ensure the potability standard (Fig. 1).

Discussion

Basic sanitation is considered a necessary condition for economic development, for the environment and for the well-being of the population[7]. Clean and safe water is critical to the health of all populations, regardless of location[8].

In Brazil, the level of service of sewage networks in urban areas of Brazilian municipalities in 2015 was 58.0%, and for municipalities located in the North of the country, only 11.2%. In relation to water supply networks, in that same year, the country's index was 93.1% and 69.2% for the North region. In Acre, the school attendance rate is around 60%[9]. The provision of water supply in households located in rural areas is 34.51%, 23.0% and 7% in the country, in the North region and Acre, respectively[6].

Although the Brazilian federal policy on basic sanitation proclaims guidelines to be followed to improve the quality of life of the population, environmental conditions and public health, and ensure by adequate means the provision of services to the dispersed rural population with solutions compatible with their economic and social characteristics, the proportion of people in rural areas without access to services is still high.

In this context, the universalization of the basic sanitation system, as well as the goals set by the National Plan for Basic Sanitation (PLANSAB) of 71%, 79% and 95% for the years 2018, 2023 and 2033, respectively, are far from being realized since, from 2014 to 2015, the reduction of investments by the state of Acre was −31.5%, only for the water supply sector[9]. Another factor that should be taken into account for non-compliance with the PLANSAB targets is the investments destined for the North and Midwest region until 2033, in the order of 10 billion dollars, since they are the lowest in relation to the other regions of the country[10].

While the global target set by the Millennium Development Goals (MDGs) of halving by 2015 the percentage of the population without sustainable access to safe drinking water was met by 2010, the same goal has not been reached for the world's rural population, since the reduction from 1990 (38%) to 2015 was 16%.

For this reason, 17 goals contemplating 169 goals were established in Agenda 2030 for Sustainable Development, among them number 6 – "ensure the availability of drinking water and sanitation for all". Of the eight goals to be achieved for this goal, we highlight two: "achieving universal and equitable access to safe and safe drinking water for all" and "strengthening the participation of local communities in improving water and sanitation management".

Although the usage of a chlorine-containing sanitizer has its effectiveness in the inactivation of recognized pathogenic microorganisms, this intervention allowed the treatment of water, combating the spread of potentially transmissible diseases and guaranteed the supply of drinking water to the students.

The relationship between sanitation and health is undeniable to all researchers in the area, since for each dollar invested in water and sanitation, us $ 4.00 in health costs is saved. in this sense thus, the use of this technology in the rural area, besides being beneficial from the ecological and economic point of view, since it reduces the investments with infrastructures for expansion of the public supply of water, also contributes to the change of the scenario of the universalization of the water supply, as well as the independence of federal, state and municipal public power, as well as fostering the empowerment and protagonist of the school community through its effective participation in water quality control. In addition, this technology represents an alternative to the conventional water supply system and goes beyond the peculiarities and difficulties of access to the rural area of Rio Branco (AC), which in the great majority is only accessible in the Amazonian summer period (July/October).

This study used the *E. coli* parameter as a determinant of the microbiological quality of water in schools. Because it is a fecal coliform, this parameter is an indicator of contamination of feces of warm-blooded organisms. Its presence the water indicates recent fecal contamination, making it unfit for consumption, and contributing to the incidence of diarrheal diseases through water containing a series of pathogens, including bacteria, viruses and protozoa, which are transmitted through the fecal–oral route[11].

However, the total coliform and turbidity parameters did not reach full compliance with the standards of the Ordinance, which is of absence in 100 mL and a maximum of 5.0 UNT, respectively. Our study differed considerably from a study conducted in the Republic of Serbia[12], which found turbidity levels above the acceptable standard of 5 UNT in 60% of the analyzed samples, against only 30%.

The percentage of unsatisfactory samples for total coliforms in this intervention (25%) also diverged from the study conducted in Morrinhos municipality, Brazil[13], since the percentage of water samples detected with total coliforms was 49.44%.

The consumption of highly turbid water may pose a health risk[12,14], since excessive turbidity can protect pathogenic microorganisms from the effect of disinfectants, as well as stimulating the growth of bacteria and contributing to a significant rise of demand for chlorine[15].

The components that contribute to the increase of turbidity can be related to the watersheds, the seasons of the year (precipitation), low pressure of the distribution system and cleaning of reservoirs; not all the increases indicate health risks associated with contamination[16,17].

In order for the chlorine action to become more efficient and eliminate microorganisms from the total coliform group, turbidity reduction is necessary, as it will avoid physical protection (biofilms) and transport of organic matter, which can be achieved improving the cleaning efficiency of the reservoirs[18]. The cleaning and disinfection of the water boxes was verified in a study carried out in 31 schools and day care centers in the city of São Carlos, Brazil, where a reduction of 50% of total coliforms occurred after notification of these educational establishments[17].

Corroborating our study, interventions in a village in Pakistan[19] and in Kitwe, Zambia[20] improved water quality safety. Another intervention in the treatment of water in 36 rural neighborhoods in eastern Ethiopia has been proven to reduce the incidence of diarrhea among children under five in a rural population where fecal contamination was high[21].

In Brazil, there is a legal framework of the Brazilian Association of Technical Standards (ABNT) that establishes the conditions required for the construction of wells for water collection of groundwater. In this study, it was observed that the systems of water collection were constructed in disagreement with the legal requirements, mainly regarding the slope of the land, the distance from the sewage system and buffering, among others. The violation of Brazilian legislation is identical to that found in a study carried out in Sichuan Province[22], since regulations in China are rarely met due to insufficient implementation and a lack of coordination between public health, education and technical departments.

The National School Feeding Program (PNAE), considered one of the largest school feeding areas in the world, aims to partially meet the nutritional needs of pre-school, elementary school, adult and youth education students enrolled in public and philanthropic schools in Brazil[23].

In order to minimize the risk of occurrence of foodborne illness in schoolchildren, each school must have a Handbook of Good Practice and Standardized Operational Procedures, developed and implemented according to their reality for practicing school food production in accordance with the criteria established by RDC 216/2004[24].

Non-compliance with this technical regulation was found in this intervention since there is no semi-annual record of hygienization of the reservoirs by a specialized company, and water connected to the public network or to an alternative network should be attested by awards. Thus and thus, the existing conditions allow the survival and multiplication of microorganisms, as well as cross-contamination with direct contact with food.

Many types of data are used to monitor the New York drinking water system as part of regular surveillance, including physical, chemical and biological measurements of water quality, as well as public health surveillance data[16].

In Brazil, the Water Quality Surveillance Program (Vigiágua) was implemented in all states, aiming to guarantee the population access to water of a quality compatible with the drinking water standard established in the current legislation of the Unified Health System (SUS). This aims to act on all the different forms of water supply, public or private, rural, urban, indigenous and isolated communities, and to systematize the data of control and surveillance in the System of Information of Surveillance of the Quality of the Water for Human Consumption (SISAGUA).

In the municipality of Rio Branco, the operation of Vigiágua is the responsibility of the Environmental Health Surveillance Division of the Municipal Health Department (SEMSA), and although the school supply form of this intervention is framed as a Collective Alternative Supply Solution of water for human consumption, the Division's responsibility was omitted in relation to this category, specifically for rural schools. However, this study provided a first step towards the recognition, registration and more complete understanding of water quality in the context of the general water quality monitoring and surveillance system within the scope of the MS, in particular the water system.

There was a lack of concern about the quality of water offered in schools, especially by students. Some teachers and principals consume bottled water purchased themselves. We have heard reports from some students that aluminum sulfate is used as a water supply treatment measure, via the surface water body; however, they are unaware of the concentration (ppm) that should be used. Studies have discussed the possible increase in cases of Alzheimer's disease or certain secondary encephalopathies of dialysis due to the consumption of water containing aluminum above levels permitted by the standards[25,26].

The cleanliness and light color of the water were interpreted as making it safe for consumption, coinciding with the findings of a study in rural West Kenya[27], demonstrating total insight with this practice. Light-colored water as a factor associated with drinking water was related to 95% of respondents from an intervention study in Southern India[28].

To sum up, suggested health education programs[29] can improve students' perceptions of the importance of water quantity and quality for health, personal hygiene care and reservoirs, as well as the protection of water sources.

This debate reinforced learning and allowed articulation between the common and scientific knowledge of the participants, as well as strengthening the partnership between the school and its users, who could act as multipliers of this knowledge in the domestic sphere. Contrary to the study conducted in the districts of Dolaka and Ramechhap, Nepal[30], it was possible to observe the students' awareness of the types of waterborne diseases and the modes of transmission. Therefore, the role of the school in transforming citizens through approaches to water-related issues, both in terms of quality and in terms of sustainable use, should be taken into account.

Several disadvantages in this intervention should be recognized and taken into account in the interpretation of the results of this study. Among them are the administration of 65% calcium hypochlorite in the simplified chlorinator depending on the availability of a school professional, because when they are absent its replacement does not occur; the lack of periodic hygiene of the reservoirs; and the location of schools in a rural area that is not accessible in winter due to lack of asphalt paving, preventing monthly monitoring. However, advantages can also be recorded: the technology costs less than US$30, is easily manipulated, and is economic for schools that need to buy water from water trucks, among others.

We recommend that school management plan actions with approaches to education in health, safety, and water quality in order to sensitize schoolchildren to the potential source of infection of apparently clear water. Likewise, public policies should ensure the expansion of interventions on water treatment to other educational establishments located in rural areas, as well as the systematic monitoring of water quality by municipal water quality monitoring. In addition, planning by the public authority for the acquisition of inputs and reagents for water analysis is of fundamental importance for the continuous monitoring of water quality.

Likewise, reservoir sanitation routines should be carried out more frequently in order not to compromise the water treatment process, and a Manual of Good Practices and Standard Operating Procedures should be prepared, aiming at the nutritional protection of school children.

Future assessments may provide important data on the sustainability of this intervention and efforts to provide safe drinking water. In this way sense, it is recommended to carry out complementary studies to identify the pathogenesis of strains of *E. coli*, emphasizing the academic and scientific importance of this type of analysis for the adoption of public health policies.

Conclusions

To conclude, the actions carried out in this intervention have considerably improved the water quality of the schools, thus reversing the health vulnerability due to inadequate water provided to the school community in the rural area.

The set of activities, including training, educational lectures, installation of equipment, supply of materials and supplies (65% calcium hypochlorite, reagents, etc.) was fundamental to the obtained result.

To this extend, it was possible to guarantee the human right of access to water, as well as to contribute to the health, well-being and food and nutritional security of the school community involved.

Since health education is one of the main actions for health promotion, we recommend that: 1) the Health Program in the school consider the theme of water as a potential source of disease transmission, seeking the learning and contextualization of the information according to the local reality; 2) other educational institutions adopt this model of water treatment, since in the scope of the actions of the School Health Program (PSE), established in Interministerial Ordinance nº 1,565 of April 25, 2017, does not contemplate this theme; and 3) the government acquire the necessary inputs for the treatment of water and distribute them to schools, as well as perform the continuous monitoring of water quality by the Environmental Surveillance of the Municipal Health Department.

References

1. Zorzi L, Turatti L, Mazzarino JM. 2016. O direito humano de acesso à água potável: uma análise continental baseada nos Fóruns Mundiais da Água. Rev Ambient & Agua - Interdisciplinary Journal of Applied Science, vol. 11, núm. 4, octubre-diciembre, pp. 954-971.

2. Malhotra S, Sidhu SK, Devi P. 2015. Assessment of bacteriological quality of drinking water from various sources in Amritsar district of northern India. J Infect Dev Ctries. 9(8):844–8. DOI: https://doi.org/10.3855/jidc.6010.

3. ECOSOC. 2017. Progress towards the Sustainable Development Goals: Report of the Secretary General. (May):1–19. Available from: https://unstats.un.org/sdgs/files/report/2017/secretary-general-sdg-report-2017-EN.pdf.

4. Jaravani FG, Massey PD, Judd J, Allan J, Allan N. 2016. Closing the Gap: the need to consider perceptions about drinking water in rural Aboriginal communities in NSW, Australia. Public Health Research & Practice. 26(2):e2621616.1–5. DOI: http://dx.doi.org/10.17061/phrp2621616.

5. Brasil. Ministério da Educação. Censo Escolar da Educação Básica. Nottas estatísticas. 2016. Brasília-DF. Available from: http://download.inep.gov.br/educacao_basica/censo_escolar/notas_estatisticas/2017/notas_estatisticas_censo_escolar_da_educacao_basica_2016.pdf.

6. Brasil. Instituto Brasileiro de Geografia e Estatística (IBGE). Sinopse do Censo Geográfico de 2010.

7. Minh, Minh, Nguyen Viet Hung. 2011. Economic Aspects of Sanitation in Developing Countries. Environ Health Insights [Internet]. Available from: http://www.la-press.com/economic-aspects-of-sanitation-in-developing-countries-article-a2871. DOI: 10.4137/EHI.S8199.

8. Whelan JJ, Willis K. 2007. Problems with provision: barriers to drinking water quality and public health in rural Tasmania, Australia. Rural Remote Heal. 7(3):627. Available from: http://www.rrh.org.au.

9. Brasil. Ministério das Cidades. Secretaria Nacional de Saneamento Ambiental (SNSA). Sistema Nacional de Informações sobre Saneamento (SNIS): Diagnóstico dos Serviços de Água e Esgoto-2015. Brasília-DF: SNSA/MCIDADES, 2017. 212p.

10. Brasil. Ministério das Cidades. Secretaria Nacional de Saneamento Ambiental (SNSA). Plano Nacional de Saneamento Básico - PLANSAB. Brasília-DF. 2013;164 p.

11. Opryszko MC, Guo Y, MacDonald L, MacDonald L, Kiihl S, Schwab KJ. 2013. Impact of water-vending kiosks and hygiene education on household drinking water quality in

rural Ghana. Am J Trop Med Hyg. 88(4):651–60. DOI:10.4269/ajtmh.12-0065.

12. Yasin M, Ketema T, Bacha K. 2015. Physico-chemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia. BMC Res Notes [Internet]. 8(1):541. DOI: 10.1186/s13104-015-1376-5.

13. Gomes Freitas D, Silva RDR, Bataus LAM, Barbosa MS, Braga CAS, Carneiro LC. 2017. Bacteriological water quality in school's drinking fountains and detection antibiotic resistance genes. Ann Clin Microbiol Antimicrob. 16(1):5. DOI: 10.1186/s12941-016-0176-7.

14. Hoko Z. 2005. An assessment of the water quality of drinking water in rural districts in Zimbabwe. The case of Gokwe South, Nkayi, Lupane, and Mwenezi districts. Phys Chem Earth. 30;859–66. DOI:10.1016/s40064-016-3676-1.

15. Gorchev HG, Ozolins G. 2011. WHO guidelines for drinking-water quality. WHO Chron. 38(3):104–8. Available from: http://www.who.int.

16. Hsieh JL, Nguyen TQ, Matte T, Ito K. 2015. Drinking water turbidity and emergency department visits for gastrointestinal illness in New York City, 2002-2009. PLoS One. 10(4):2002–9. DOI: 10.1371/journal.pone.0125071.

17. Scuracchio PA, Filho AF. 2011. Qualidade da água utilizada para consumo em escolas e creches no município de São Carlos-SP. Alim Nutr, Araraquara. 641–647.

18. Silva LJ, Lopes LG, Amaral LA. 2016. Qualidade da água de abastecimento público do município de Jaboticabal, SP. Eng Sanit e Ambient [Internet]. 21(3):615–22. DOI: 10.1590/S1413-41522016121151.

19. Jensen PK, Ensink JHJ, Jayasinghe G, van der Hoek W, Cairncross S, Dalsgaard A. 2003. Effect of chlorination of drinking-water on water quality and childhood diarrhoea in a village in Pakistan. J Heal Popul Nutr. 21(1):26–31. Available from: http://www.jstor.org/stable/23498831.

20. Quick RE, Kimura A, Thevos A, Tembo M, Shamputa I, Hutwagner L, Mintz E. 2002. Diarrhea prevention through household-level water disinfection and safe storage in Zambia. Am J Trop Med Hyg. 66(5):584–9.

21. Mengistie B, Berhane Y, Worku A. 2013. Household Water Chlorination Reduces Incidence of Diarrhea among Under-Five Children in Rural Ethiopia: A Cluster Randomized Controlled Trial. PLoS One. 8(10):1–7. https://doi.org/10.1371/journal.pone.0077887.

22. He F, Han K, Liu L, Sun W, Zhang L, Zhu B, Ma H. 2012. Shigellosis Outbreak Associated with Contaminated Well Water in a Rural Elementary School: Sichuan Province, China, June 7-16, 2009. PLoS One. 7(10):16–9. https://doi.org/10.1371/journal.pone.0047239.

23. Brasil. Ministério da Educação. Portal do Fundo Nacional de Desenvolvimento da Educação. 2010. Disponível em: <http://www.fnde.gov.br>. Acesso em: 12 jul. 2017.

24. BRASIL. Ministério da Saúde. Agência Nacional de Vigilância Sanitária (ANVISA). Resolução RDC nº 216, de 15 de setembro de 2004. [Internet]. 2004;1–14. Disponível em: <http://www.anvisa.gov.br>.

25. Freitas MB, Brilhante OM, Almeida LM. 2001. The importance of water testing for public health in two regions in Rio de Janeiro: a focus on fecal coliforms, nitrates, and aluminum. Cad. Saúde Pública. 17(3):651–60. http://dx.doi.org/10.1590/S0102-311X2001000300019.

26. Muniz JM. 2013. Avaliação microbiológica, física e química da água de escolas públicas municipais de Uberaba – MG. Dissertação (Mestrado). Instituto Federal do Triângulo Mineiro. 141 P.

27. Onyango-Ouma W, Gerba CP. 2011. Away-from-home drinking water consumption practices and the microbiological quality of water consumed in rural western Kenya. J Water Health. 9(4):628–36. DOI: 10.2166/wh.2011.115.

28. Freeman MC, Clasen T. 2011. Assessing the impact of a school-based safe water intervention on household adoption of point-of-use water treatment practices in Southern India. Am J Trop Med Hyg. 84(3):370–8. DOI: 10.4269/ajtmh.2011.10-0361.

29. Lindskog RUM, Lindskog PA. 1988. Bacteriological contamination of water in rural areas: an intervention study from Malawi. J Trop Med Hyg [Internet]. 91(1):1–7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/3346930.

30. Shrestha A, Sharma S, Gerold J, Erismann S, Sagar S, Koju R, Schindler C, Odermatt P, Utzinger J, Cissé G. 2017. Water quality, sanitation, and hygiene conditions in schools and households in dolakha and ramechhap districts, Nepal: Results from a cross-sectional survey. Int J Environ Res Public Health. 14(1):1–21. DOI: 10.3390/ijerph14010089.

Figure 1(on next page)

Infographic of the environmental intervention study

Strategic plan and action steps during the environmental intervention study. Intervention means both chlorinator installation and environmental education approach (training, lectures, and kit delivery) in the rural schools.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26475v1 | CC BY 4.0 Open Access | rec: 31 Jan 2018, publ: 31 Jan 2018


SCHOOL
Selection and initial data collection
Chlorinator
Training
Lectures and kits delivery
Photometer
Monitoring and final data collection

Figure 2 (on next page)

Location map of the sixty-five schools in the rural area of Rio Branco municipality, Acre state.

Schools with intervention (pink triangles) were studied in the present study and schools without intervention (yellow squares) were selected for a future research with a wider health care intervention approach.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26475v1 | CC BY 4.0 Open Access | rec: 31 Jan 2018, publ: 31 Jan 2018

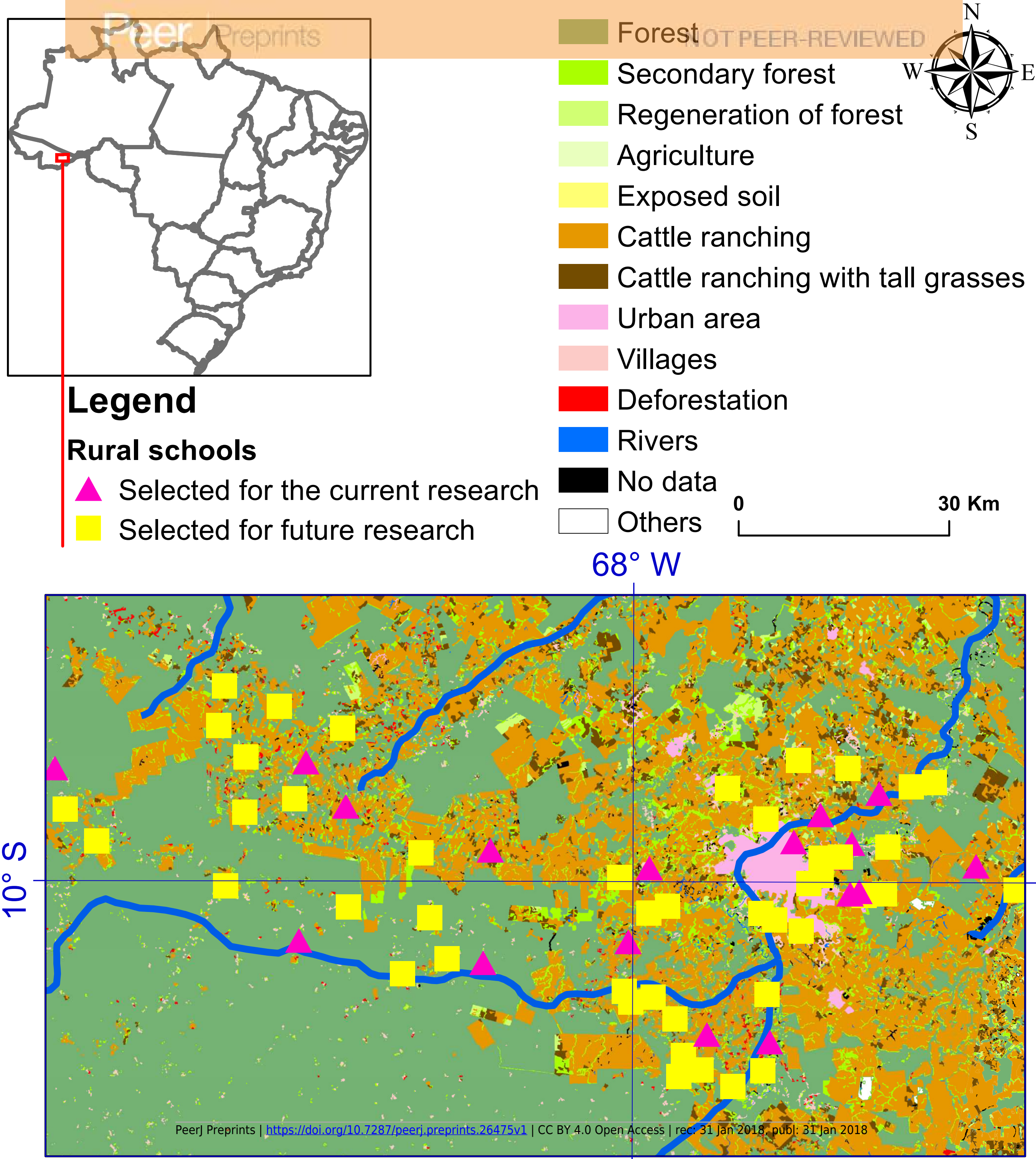

Legend
Rural schools
Selected for the current research
Selected for future research
Forest
Secondary forest
Regeneration of forest
Agriculture
Exposed soil
Cattle ranching
Cattle ranching with tall grasses
Urban area
Villages
Deforestation
Rivers
No data
Others
0
30 Km
N
S
W
E
68° W
10° S

Figure 3(on next page)

Results of turbidity analysis before and after intervention.

Water potability analyses of 20 (twenty) schools located in the rural area of the Rio Branco municipality, Acre state, 2016-2017. Turbidity results were not different before and after intervention (P = 0.71).

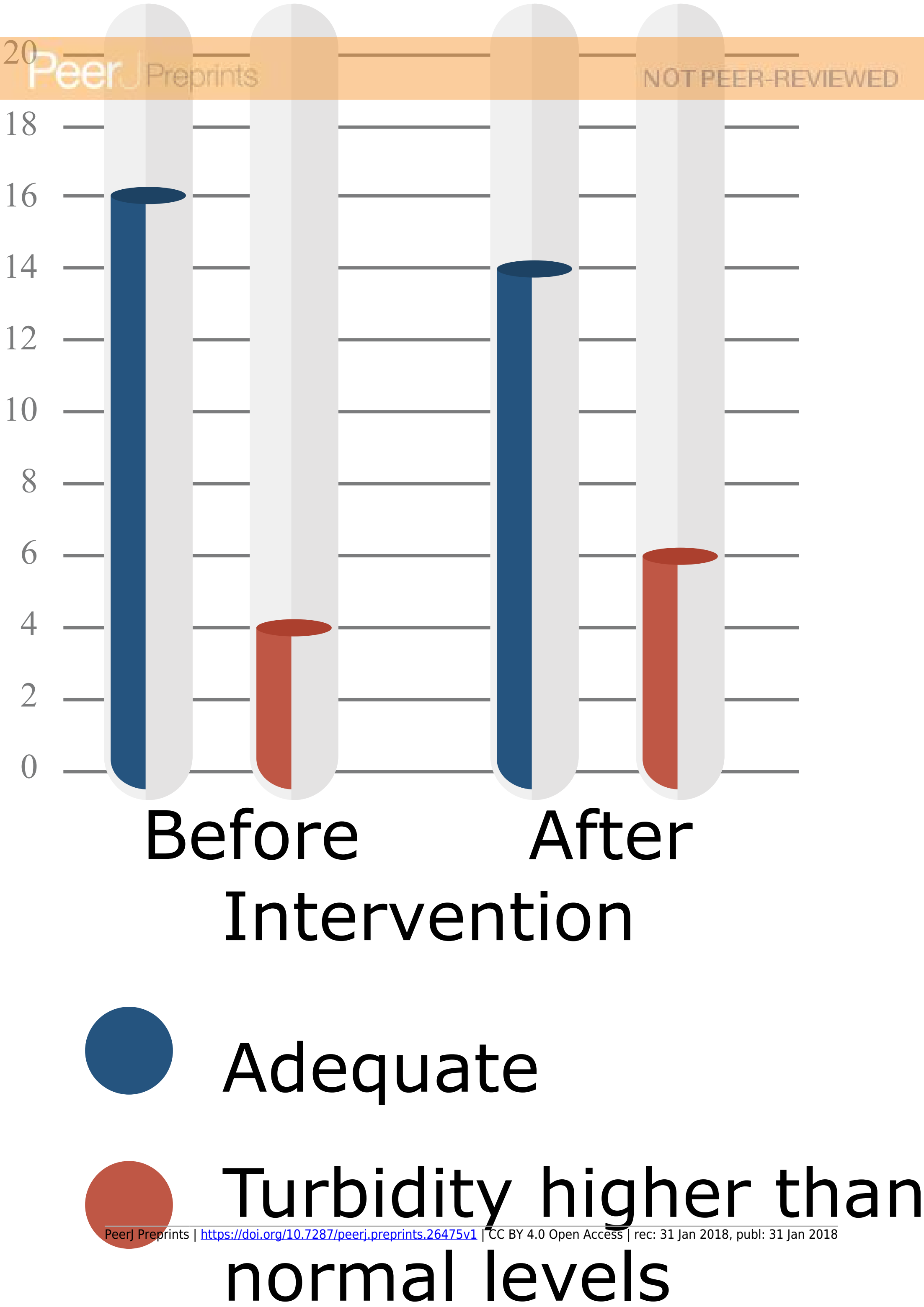
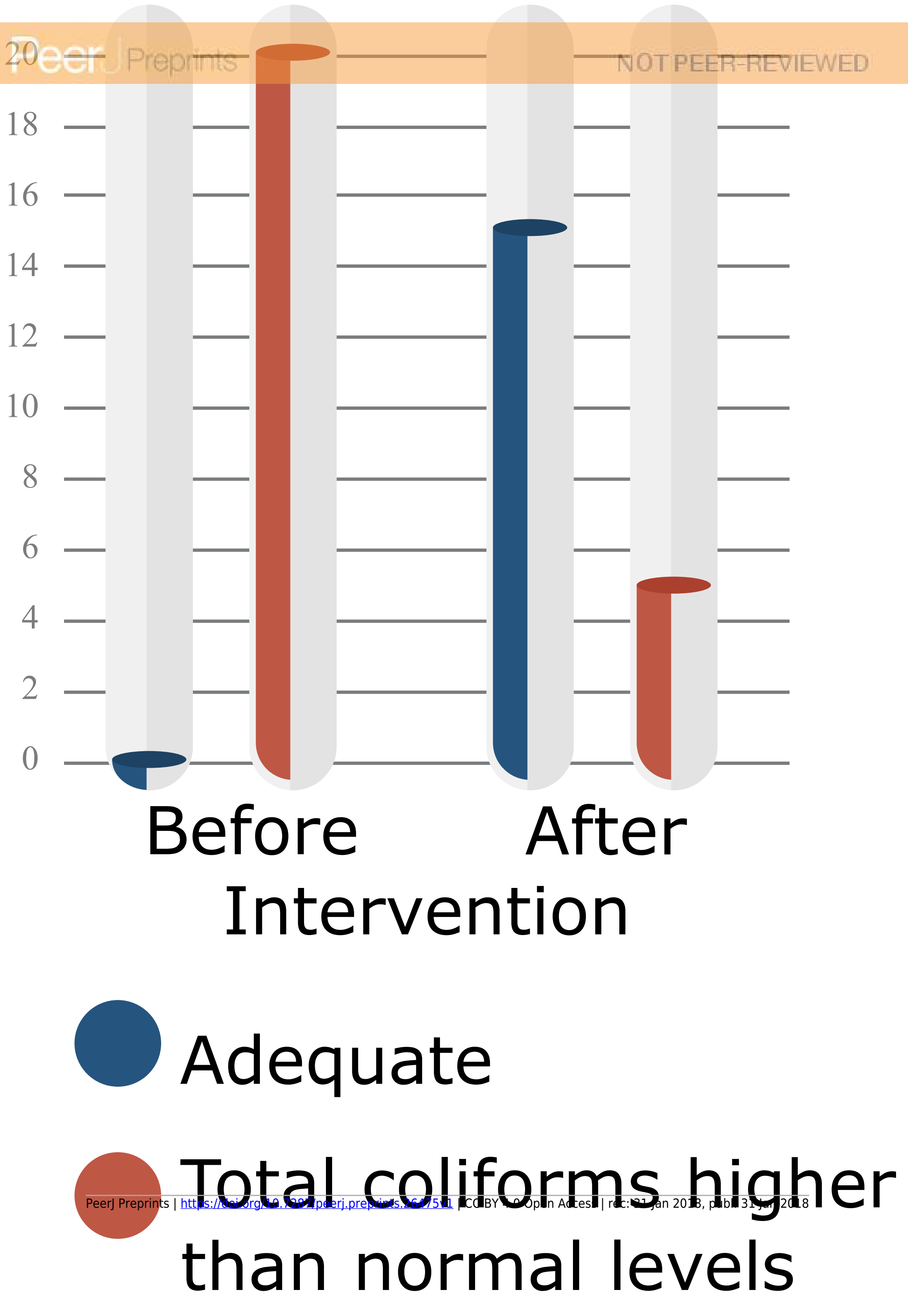

20
18
16
14
12
10
8
6
4
2
0
Before
After
Intervention
Adequate
Turbidity higher than normal levels

Figure 4 (on next page)

Results of faecal coliform analysis before and after intervention.

Water potability analyses of 20 (twenty) schools located in the rural area of the Rio Branco municipality, Acre state, 2016-2017. Faecal coliform levels were lower after intervention ($p < 0.001$).



20
18
16
14
12
10
8
6
4
2
0
Before
After
Intervention
Adequate
Total coliforms higher than normal levels

Figure 5(on next page)

Results of *Escherichia coli* analysis before and after intervention.

Water potability analyses of 20 (twenty) schools located in the rural area of the Rio Branco municipality, Acre state, 2016-2017. *Escherichia coli* levels were much lower after intervention ($p < 0.001$).

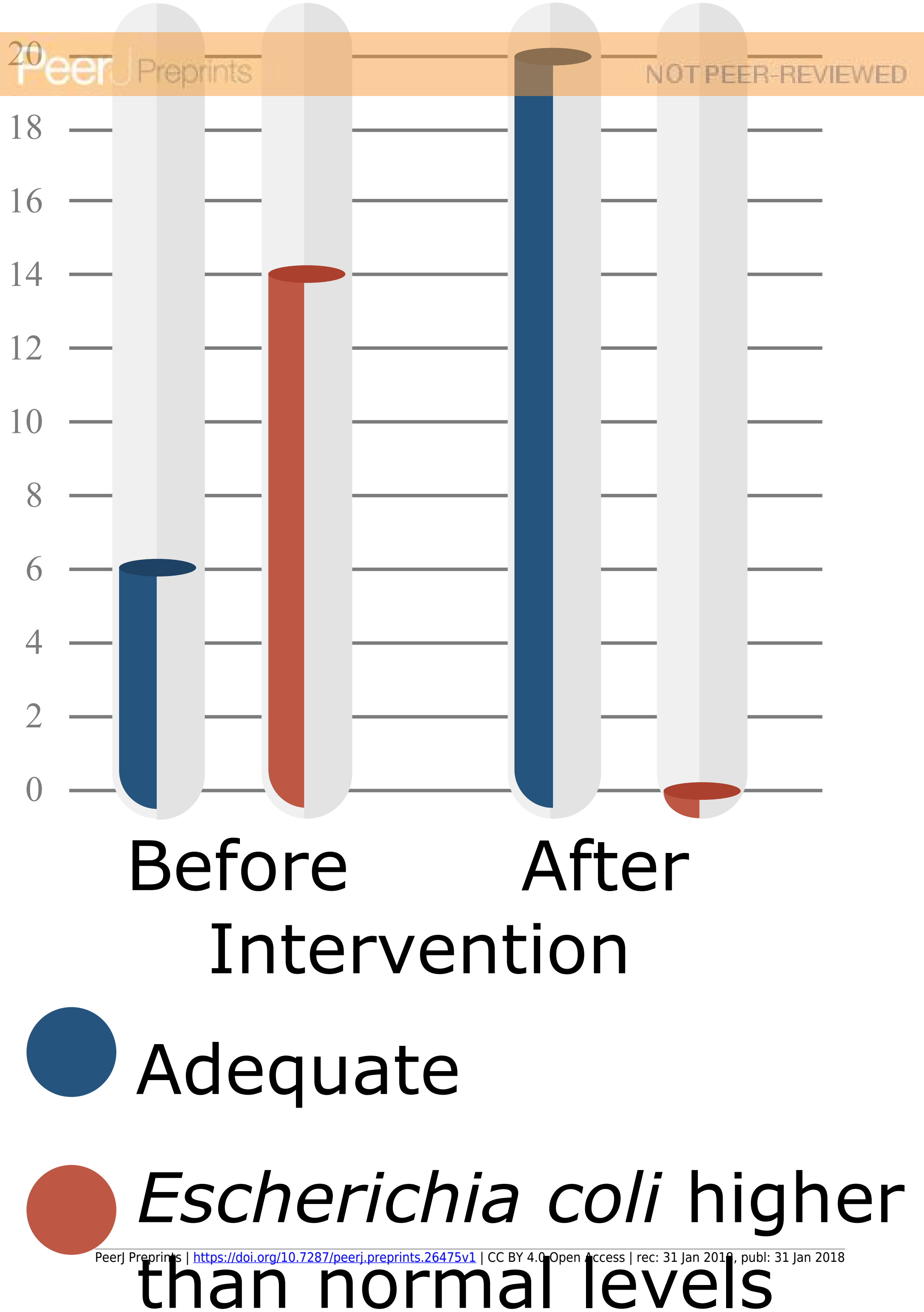

20
18
16
14
12
10
8
6
4
2
0
Before
After
Intervention
Adequate
Escherichia coli higher than normal levels

Table 1 (on next page)

Schools analyzed in the rural area of the municipality of Rio Branco, Acre state

Type of administration, number of students enrolled, minimum and maximum students age, source of water supply and intervention status.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26475v1 | CC BY 4.0 Open Access | rec: 31 Jan 2018, publ: 31 Jan 2018

Table 1. Schools analyzed in the rural area of the municipality of Rio Branco-AC: type of administration, number of students enrolled, minimum and maximum students age, source of water supply and intervention status**.**

School I.D.	Management	Number of students	Age		Source of supply	Intervention
			Min.	Max.		
1	State	24	8	40	Acre river	No
2	State	10	6	13	Amazonas-Cacimbão well	No
3	State	65	4	50	Amazonas-Cacimbão well /Water truck	No
4	**State**	**25**	**6**	**12**	**Amazonas-Cacimbão well**	**Yes**
5	State	50	6	20	Local river	No
6	State	147	6	61	Local water reservoir	No
7	State	105	6	13	Semi-artesian well	No
8	**Municipal**	**83**	**3**	**6**	**Amazonas-Cacimbão well**	**Yes**
9	State	25	6	12	Semi-artesian well	No
10	State	17	6	13	Amazonas-Cacimbão well	No
11	**State**	**70**	**6**	**55**	**Amazonas-Cacimbão well**	**Yes**
12	State	10	6	13	Amazonas-Cacimbão well	No
13	State	15	5	12	Amazonas-Cacimbão well	No
14	State	24	7	24	Amazonas-Cacimbão well	No
15	State	29	7	26	Iguarape	No
16	**State**	**129**	**7**	**20**	**Amazonas-Cacimbão well**	**Yes**
17	**State**	**145**	**6**	**20**	**Amazonas-Cacimbão well**	**Yes**
18	State	21	6	14	Semi-artesian well	No
19	State	572	8	22	Local water reservoir/Water truck	No
20	State	NI*	6	17	Semi-artesian well	No
21	**Municipal**	**210**	**4**	**15**	**Semi-artesian well**	**Yes**
22	State	350	10	29	Semi-artesian well	No
23	State	101	5	28	Semi-artesian well	No
24	State	15	6	13	Amazonas-Cacimbão well	No
25	State	187	4	14	Water truck	No
26	State	225	6	12	Water truck	No
27	State	21	7	12	Local water reservoir	No
28	State	9	6	11	Amazonas-Cacimbão well	No
29	**State**	**100**	**4**	**20**	**Amazonas-Cacimbão well**	**Yes**
30	State	36	6	26	Amazonas-Cacimbão well	No
31	State	25	5	35	Amazonas-Cacimbão well	No
32	State	13	6	10	Semi-artesian well	No
33	State	10	6	10	Amazonas-Cacimbão well	No
34	**State**	**298**	**6**	**21**	**Amazonas-Cacimbão well**	**Yes**
35	State	16	8	15	Local river	No
36	**State**	**440**	**6**	**60**	**Semi-artesian well**	**Yes**
37	State	102	6	17	Semi-artesian well	No
38	**Municipal**	**40**	**2**	**3**	**Semi-artesian well**	**Yes**
39	**Municipal**	**186**	**6**	**18**	**Amazonas-Cacimbão well /Water truck**	**Yes**
40	Municipal	363	6	14	Semi-artesian well	No
41	**State**	38	6	13	Amazonas-Cacimbão well	No
42	**Municipal**	**12**	**7**	**14**	**Amazonas-Cacimbão well**	**Yes**
43	**State**	16	7	14	Amazonas-Cacimbão well	No
44	**State**	**162**	**6**	**25**	**Amazonas-Cacimbão well**	**Yes**

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26475v1 | CC BY 4.0 Open Access | rec: 31 Jan 2018, publ: 31 Jan 2018

45	**State**	**26**	**5**	**12**	**Semi-artesian well**	**Yes**
46	State	24	6	17	Iguarape	No
47	State	194	4	14	Water truck	No
48	Municipal	50	6	18	Amazonas-Cacimbão well	No
49	**Municipal**	**218**	**4**	**13**	**Semi-artesian well**	**Yes**
50	**Municipal**	**25**	**6**	**15**	**Amazonas-Cacimbão well**	**Yes**
51	**State**	27	5	12	Amazonas-Cacimbão well	No
52	**State**	198	5	14	Semi-artesian well	No
53	**State**	310	6	22	Semi-artesian well/Water truck	No
54	**State**	**336**	**11**	**17**	**Semi-artesian well**	**Yes**
55	State	222	4	26	Semi-artesian well	No
56	State	45	6	58	Amazonas-Cacimbão well	No
57	Municipal	30	6	14	Semi-artesian well	No
58	State	7	6	14	Local water reservoir	No
59	State	31	15	24	Amazonas-Cacimbão well	No
60	Municipal	65	6	70	Amazonas-Cacimbão well	No
61	State	55	7	15	Amazonas-Cacimbão well	No
62	Municipal	23	6	13	Amazonas-Cacimbão well	No
63	**State**	**130**	**5**	**45**	**Amazonas-Cacimbão well**	**Yes**
64	**Municipal**	**186**	**4**	**14**	**Water truck**	**Yes**
65	**State**	**125**	**6**	**12**	**Semi-artesian well**	**Yes**

4

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.26475v1 | CC BY 4.0 Open Access | rec: 31 Jan 2018, publ: 31 Jan 2018