Updating national standards for drinking-water: a Philippine experience

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ABSTRACT

The latest version of the Philippine National Standards for Drinking-Water (PNSDW) was issued in 2007 by the Department of Health (DOH). Due to several issues and concerns, the DOH decided to make an update which is relevant and necessary to meet the needs of the stakeholders. As an output, the water quality parameters are now categorized into mandatory, primary, and secondary. The ten mandatory parameters are core parameters which all water service providers nationwide are obligated to test. These include thermotolerant coliforms or *Escherichia coli*, arsenic, cadmium, lead, nitrate, color, turbidity, pH, total dissolved solids, and disinfectant residual. The 55 primary parameters are site-specific and can be adopted as enforceable parameters when developing new water sources or when the existing source is at high risk of contamination. The 11 secondary parameters include operational parameters and those that affect the esthetic quality of drinking-water. In addition, the updated PNSDW include new sections: (1) reporting and interpretation of results and corrective actions; (2) emergency drinking-water parameters; (3) proposed Sustainable Development Goal parameters; and (4) standards for other drinking-water sources. The lessons learned and insights gained from the updating of standards are likewise incorporated in this paper.

Key words | drinking-water quality, Philippines, standards

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INTRODUCTION

Safe drinking-water is a vital life-sustaining need for human beings. However, there are human populations globally who are deprived of access to this essential resource. In 2012, the WHO reported that diarrheal disease comprised 3.6% of the total global burden of disease and is responsible for the deaths of 1.5 million people every year (World Health Organization 2012). Fifty-eight percent (58.0%) of these deaths is attributable to unsafe water supply, sanitation and hygiene. In the Philippines, diarrhea and other waterborne diseases are still the leading causes of morbidity (PSA 2014). In 2014, more diarrheal outbreaks were reported due to the presence of pathogenic microorganisms in contaminated water supply. This crisis hindered the progress towards achieving relevant Millennium Development Goals (MDGs).

According to the WHO (2011), 'the quality of drinking water is a powerful environmental determinant of health'. The maintenance of drinking-water quality is, therefore, vital in preventing the spread of waterborne diseases. In view of this, the Department of Health (DOH) has developed the Philippine National Standards for Drinking-Water (PNSDW). The first version of the PNSDW was published in the year 1963. It was based on the 1958 WHO International Standard for Drinking Water and the 1962 United States Public Health Service Standards. Later in 1978, the 1963 standards were revised. The standards were intended to guide waterworks officials, employees and private persons or agencies supplying water to the public and other health and sanitation authorities. This resulted in the circulation of an

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Administrative Order which included microbiological, radiological, and 49 physical and chemical parameters. Likewise, it reflected the standard methods for water analysis published by the Ministry of Human Settlements and Ecology to guarantee that procedures for analysis allowed the comparison of test results within and between laboratories. In 1993, the standards were further revised. This revision delineated the parameters with significant impacts on health and parameters which affect the acceptability of water for drinking. A third revision of the standards resulted in the 2007 PNSDW which considered developments in the water supply sector including: (i) new chemicals used in agricultural, industrial, or domestic-related activities; (ii) loss of confidence of the public in drinking-water supplied by utilities, hence, the proliferation of water refilling stations (WRS) and water vending machines as alternative sources of drinking-water; (iii) detection of naturally occurring hazardous substances in groundwater; and (iv) the need for different approaches in supporting safe management of water supply systems (DOH 2007).

Nine years have lapsed since the PNSDW was revised. Since then a number of issues and concerns from various stakeholders have emerged. Among these are: (i) experiences of water service providers in complying with the standards; (ii) publication of the fourth edition of the Guidelines for Drinking-Water Quality by the World Health Organization, which includes new parameters and an improved framework for drinking-water safety that should be considered in water quality monitoring, testing, and analysis; (iii) issuance of DOH Administrative Order Number 2014-0027, which requires all drinking-water service providers to develop and implement water safety plans; (iv) new scope and definitions of Sustainable Development Goal (SDG) water supply indicators; and (v) the need for water quality standards during emergency situations. These issues and concerns served as bases for DOH to update the standards and make them more responsive to the needs of all stakeholders, including the general public.

This paper summarizes the results of the updated PNSDW, including the new set of mandatory, primary, and secondary parameters and the new sections on: (1) reporting and interpretation of results and corrective actions; (2) emergency drinking-water parameters; (3) proposed SDG parameters; and (4) standards for other drinking-water sources. The lessons learned and insights gained from updating the standards are likewise presented in this paper.

METHODS

A technical working group (TWG) composed of key government regulatory agencies and water supply experts was organized. In addition, a project management team was hired to assist the DOH in the updating of the drinking-water standards (Appendix 1, available with the online version of this paper).

A series of workshops and consultative meetings with the TWG were conducted from February 2015 to November 2015 to determine the scope, objectives, content, definitions, methods of analysis, and water quality parameters. The discussions were supported by data gathered using self-administered questionnaires and focus group discussions among water service providers and regulators, sanitary inspectors, and representatives from local government units (LGUs) and review of relevant literature such as the 2011 WHO Guidelines for Drinking-Water Quality, 2011 Australian Drinking Water Quality Guidelines, 2012 US EPA Table of Regulated Drinking-Water Contaminants and 22nd edition of the Standard Methods for Examination of Water and Wastewater (SMEWW).

Consultants from the WHO, Geneva, were likewise invited to provide inputs on the risk-based method in drinking-water standards development. In particular, they provided guidance on the prioritization of mandatory parameters based on the occurrence of the parameter together with its health and acceptability risks. The final draft of the PNSDW was presented to key stakeholders in a national consultation in November 2015 and sub-national public consultations in Visayas, Mindanao, and Luzon in April, May, and June, 2016, respectively. The comments of stakeholders were discussed by the TWG in a workshop held in August 2016. The document was then revised based on the consensus of the TWG members.

RESULTS AND DISCUSSION

The updated PNSDW covers comprehensive parameters in measuring water quality including the physical, chemical,

microbiological, and radiological compositions of water. It delineates the values established to prevent the adverse health effects of the parameters, as opposed to values established purely to satisfy esthetic requirements. The standards likewise advocate for an efficient water quality surveillance system by prioritizing parameters that need to be monitored using the risk-based approach. The standards for drinking-water quality for water, sanitation and hygiene (WASH) emergency response, rehabilitation and recovery are incorporated in view of the identified needs from the recent calamities that have hit the country. The increasing use of various treatment techniques, such as reverse osmosis (RO) by small-scale water service providers in the country, is likewise considered in the identification of standards for other sources of drinking-water.

The updating of the 2016 PNSDW was a well-planned process, involving a series of consultations with the TWG, stakeholders, and experts from the WHO. The experiences of water service providers, regulators, and laboratories contributed to the inclusion of specific guidelines in the PNSDW. A consistent and accurate documentation of activities is very necessary and important in the updating of standards. The minutes of meetings and consultations submitted to the WHO Country Office and the DOH can serve as bases for the methods and processes to be undertaken in subsequent updates.

Mandatory, primary, and secondary parameters

The TWG prioritized water quality parameters based on the following criteria: (i) impacts on health and acceptability of drinking-water; (ii) likelihood of presence in the country; and (iii) presence of an approved method for testing. The output of updating conducted includes the water quality parameters classified as mandatory, primary, and secondary.

Mandatory parameters are core parameters which all water service providers nationwide are required to test. These parameters are considered mandatory because they: (i) directly affect health through acute or chronic exposure and/or will render the water unacceptable for drinking; (ii) indicate the possible presence of other contaminants; (iii) exceed standards based on local monitoring data from the previous years; (iv) have wide spatial distribution across the Philippines based on local monitoring data; and (v) are viable indicators for general quality and stability of water supply. With these considerations, the TWG identified ten mandatory parameters as shown in Table 1. While some of these parameters (i.e., pH, residual chlorine, and turbidity) are strictly operational in nature, the inclusion in the updated PNSDW is justified because these are indicative of some water quality issues. In addition to the ten mandatory parameters, total coliform and heterotrophic plate count are set as mandatory parameters for treated water as these indicate sanitary conditions and the effectiveness of water treatment processes (WHO 2003). A number of acceptability and operational parameters were included in the list of mandatory parameters because these indicate the efficiency of water treatment and/or the general stability of water quality. In addition, the acceptability parameters will affect the choices of consumers. However, these parameters were limited in number because these could be easily covered by general conditions. More often than not, parameters are rejected at concentrations lower than those of health concerns as these may render drinking-water esthetically unappealing. In such cases, direct regulation or monitoring of those parameters will not be necessary. Chlorine dioxide was likewise included

Table 1 | Mandatory drinking-water quality parameters and their standard values

Parameter	Standard values
Thermotolerant coliform or *E. coli*	MTFT: <1.1 MPN/100 mL
	EST: Absent or <1 MPN/100 mL
	MFT: <1 thermotolerant coliform colonies/100 mL
Arsenic	0.01 mg/L
Cadmium	0.003 mg/L
Lead	0.01 mg/L
Nitrate	50.00 mg/L
Color	10 CU
Turbidity	5.0 NTU
pH	6.5–8.5
TDS	500 mg/L
Disinfectant residual	Chlorine residual: 0.3 mg/L min and 1.5 mg/L max
	Chlorine dioxide residual: 0.2 mg/L min and 0.4 mg/L max

MTFT, multiple tube fermentation technique; EST, enzyme substrate technique; MFT, membrane filtration technique.

as a mandatory parameter, along with other disinfectant residual. In the previous versions of the PNSDW, chlorine dioxide was not regulated. However, the increasing use of the disinfectant by water service providers prompted the TWG to set standards for chlorine dioxide. The process of review and updating showed that other countries like the United States and Australia have standards and guidelines values for chlorine dioxide.

The list of mandatory parameters can be expanded by the LGUs through the Local Drinking-Water Quality Monitoring Committee (LDWQMC), after an assessment was conducted using the risk-based approach. The risk-based approach is a valuable tool in standards setting but is only applicable to individual systems where site-specific risks and hazards can be identified (Jackson 2015). It is likewise heavily dependent on databases, particularly the extent of how well existing water quality is understood. With this provision in the updated PNSDW, the testing of certain primary and secondary parameters may be made mandatory if water sources in a particular locality are at high risk of being contaminated by natural sources and/or anthropogenic activities in the area.

Primary parameters are site-specific parameters which directly affect health through acute or chronic exposure. There are 55 primary parameters included in the updated PNSDW. The list consists of selected chemical and radiological parameters, which were prioritized based on their effects on health (Table 2). The capability of testing parameters like radiological contaminants in water was a concern presented by stakeholders during the sub-national consultations. The TWG, however, has recommended tapping laboratories outside the country for the testing of these parameters; hence, capability should not hinder the testing of health-significant parameters. The nationwide assessment of radiological parameters is likewise being considered to identify areas in the country which are likely to have problems related to radiological contaminants. On the other hand, secondary parameters affect the acceptability of water for drinking. These parameters likewise affect the efficiency of the treatment processes and therefore include operational parameters. There are 11 secondary parameters including aluminum, chloride, copper, total hardness, hydrogen sulfide, iron, odor, sodium, taste, zinc, and xylenes (total). The testing for mandatory bacteriological parameters shall be done on a monthly basis whereas the physico-chemical parameters shall be tested once or twice year, depending on the source and mode of supply. The number of samples that will be collected from the distribution system will vary depending on the population served.

Table 2 | List of primary drinking-water quality parameters

1. 1,2-Dibromo-3-chloropropane (DBCP)	28. Di(2-ethylhexyl)phthalate
2. 1,2-Dichlorobenzene	29. Dibromochloromethane (DBCM)
3. 1,2-Dichloroethane	30. Dibromoacetonitrile
4. 1,2-Dichloroethene	31. Dichloroacetate
5. 1,4-Dichlorobenzene	32. Dichloroacetonitrile
6. 2,4,6-Trichlorophenol	33. Dichlorodiphenyltrichloroethane (DDT)
7. Acrylamide	34. Dichloromethane
8. Aldrin and dieldrin	35. Endrin
9. Alpha particles	36. Epichlorohydrin
10. Atrazine	37. Ethylbenzene
11. Antimony	38. Ethylene dibromide
12. Barium	39. Fluoride
13. Benzene	40. Glyphosate
14. Benzo(a)pyrene (PAHs)	41. Lindane
	42. Manganese
15. Beta particles	43. Mercury (total)
16. Boron	44. Monochloroacetate
17. Bromate	45. Nickel
18. Bromodichloromethane (BDCM)	46. Nitrite
19. Bromoform	47. Pendimethalin
20. Carbon tetrachloride	48. Radon
21. Carbofuran	49. Sulfate
22. Chlorate	50. Selenium
23. Chlordane	51. Styrene
24. Chlorite	52. Tetrachloroethene
25. Chloroform	53. Trichloroacetate
26. Chromium (total)	54. Toluene
27. Cyanide (total)	55. Vinyl chloride

The process of updating revealed the need to maintain a database of water quality monitoring data, which is presently inadequate. The prioritization of parameters through the risk-based approach was limited by the lack of a comprehensive database on water quality monitoring data in the

country. Water service providers are required to submit reports of laboratory analysis to regulatory agencies. However, the data are not consolidated, analyzed, and evaluated so that these can be utilized for decision-making. In addition to the lack of consolidated water quality monitoring data, there is also a need to map out possible sources of contaminants in the country. This limitation could have been met by the identification of an agency or office tasked mainly to carry out these functions. Academic institutions can provide the technical assistance needed for such activities. The information that can be gathered from these will not only help in the selection of parameters but also in the regionalization of parameters. Different areas in the Philippines have unique characteristics; hence the need for regional standards. In addition, the prioritization of parameters on a regional level can be strengthened by the capacity-building of LGUs and water service providers on the risk-based approach.

Standard values and methods of analysis

The standard values and methods of analysis of the different parameters in the 2007 PNSDW, 2011 WHO Guidelines for Drinking-Water Quality, 2011 Australian Drinking-Water Guidelines, and 2012 US Environmental Protection Agency were reviewed as part of the process of updating the PNSDW.

The standard values adopted in the updated PNSDW were concentrations of the parameters that do not produce any significant, unfavorable consequence to human health over a lifetime of consumption (NHMRC 2011). However, esthetic guideline values were also considered because water is usually rejected because of unacceptable taste, color, and odor, even at concentrations lower than those of health concern (WHO 2011). Moreover, these may drive consumers to find alternative sources of drinking-water which are more hazardous to health. Based on discussions by the TWG, most of the standard values for the mandatory, primary, and secondary parameters were adopted from the 2011 WHO Guidelines for Drinking-Water Quality because these were deemed appropriate for the Philippine setting. Moreover, there was sufficient evidence to show the effects of water quality parameters at levels exceeding the standard values.

The TWG likewise made reference to the 22nd edition of the Standard Methods for the Examination of Water and Wastewater (SMEWW) for the recommended methods of testing. For each parameter, corresponding standard methods from the SMEWW and the 2007 PNSDW were listed and reviewed by the TWG. Members of the TWG and stakeholders from laboratory facilities in the country facilitated the update, review, and selection processes by confirming which methods are available and appropriate for the local setting. The method detection limits were likewise reviewed to ensure that regulatory standards will be met by the proposed analytical methods. The TWG decided to adopt specific methods of analysis from the 22nd edition of SMEWW. This was done to standardize the analysis of water quality parameters in the country. It was observed that in the 2007 PNSDW, the standardization of analytical methods was hindered by the lack of specific method numbers.

Reporting and interpretation of results and corrective actions

In the Philippines, water service providers are required to regularly submit water quality monitoring reports to the concerned regulatory agency for evaluation. In order to standardize reporting, laboratories shall use the terms 'complying' or 'non-complying' with the PNSDW to indicate the results of microbiological and physico-chemical tests on water. The 2016 PNSDW incorporates guidelines for the reporting and interpretation of results to standardize the current system of reporting in the country. At present, laboratory testing facilities make use of the terms 'passed', 'failed', 'satisfactory', 'unsatisfactory', 'above limit', 'within limit' in the interpretation of the results of microbiological and physico-chemical tests. The development of these guidelines entailed comprehensive consultations with key representatives from laboratory testing facilities to ensure the appropriateness of the proposed system of reporting laboratory results. The participation of laboratories in developing the guidelines was maximized through the conduct of national and sub-national consultations.

In the case of exceedance of standard values of drinking-water quality parameters, an investigation to determine the cause shall be conducted immediately while the quality of

the water supply is monitored simultaneously. Monitoring shall be carried out monthly for three consecutive months wherein all results shall comply with the updated PNSDW. The monitoring results can serve as the bases for applying treatment and other remediation measures. Within 24 hours, the local government through the LDWQMC is expected to issue an advisory that the water is not safe for consumption. The advisory shall be made if the level of contamination remains consistently high even after treatment or corrective actions have been implemented. During the correction period, the water service provider is required to provide substantial quantity and good quality of water to the affected consumers. The aforementioned guidelines in the updated PNSDW are aligned with the provisions of the Implementing Rules and Regulations (IRR) of Chapter II: Water Supply of the Code on Sanitation of the Philippines (DOH 1995). The inclusion of these guidelines shall help the LGUs and field personnel in immediately responding to incidents involving exceedances in contaminant levels in water. In such cases, corrective actions may be instituted immediately as a means of protecting public health.

On the other hand, if consolidated water quality reports from a locality show that a particular mandatory parameter has been undetectable for three consecutive years, the frequency of testing for that specific parameter may be reduced to every three years, provided that there is no possible source of a particular chemical in the area. Water service providers shall coordinate with the LDWQMC for the implementation of such guideline. It has been noted that, in the 2007 PNSDW, some mandatory parameters like benzene were undetectable in water samples. The 2016 PNSDW shall address similar concerns through the inclusion of guidelines for the reduction in the frequency of sampling for drinking-water samples. The experiences of water service providers were taken into consideration in the formulation of these guidelines. These guidelines are developed in view of the concerns of water service providers regarding the considerable cost of testing for water quality parameters.

Emergency drinking-water parameters

Several emergency drinking-water parameters were recommended for inclusion in the updated PNSDW, based on existing international and local literature and the experiences of local experts after Typhoon Haiyan. These include: (1) thermotolerant coliforms; (2) *Escherichia coli*; (3) residual chlorine; (4) pH; (5) turbidity; and (6) other chemical and radiological parameters (WHO 2002; DOH 2011; Magtibay *et al.* 2015). These parameters were presented to the TWG, but in the result of their deliberation, only residual chlorine and *E. coli* were deemed necessary to be tested immediately at the onset of the emergency. The updated PNSDW specifically states that *E. coli* shall be absent from emergency drinking-water and that 0.5–1.5 mg/L of residual chlorine shall be maintained in the drinking-water supply. For this reason, public advisories will be made to boil or chlorinate drinking-water considering that only microbiological contaminants, if present, will have acute health effects. During emergencies, water treatment shall not be limited to boiling or chlorination. Other methods of disinfection may be applied if these are suitable to the emergency situation. In terms of monitoring, the TWG decided that daily monitoring of the water supply shall be done for at least 7 days by the LGU and other respondents using portable test kits. Testing for other mandatory parameters shall be done when normal condition has been declared. The conduct of researches related to drinking-water quality during emergencies is considered useful and necessary in setting standards for drinking-water quality during emergency situations.

Proposed SDG parameters

SDGs are targets for international development based on the MDGs. Every government should adopt its own national targets guided by the global level of expectation. In the context of drinking-water quality, the sector on WASH proposed the goal of achieving universal and equitable access to safe and affordable drinking-water for all by the year 2030. This necessitates that the population uses a basic drinking-water source which is located in the area and available when needed. This drinking-water should be free from fecal (and priority chemical) contamination and/or regulated by a competent authority (Johnston 2015). In line with the goal of the WASH sector, the updated PNSDW proposes the inclusion of the ten mandatory water quality parameters as SDG indicators.

Standards for other sources of drinking-water

The quality of the product water varies depending on the treatment techniques employed. In the Philippines, small-scale water service providers such as WRS and water vending machines use purification techniques like RO, distillation, nano-filtration, and ultra-filtration. Water treated using these techniques are considered suitable for human consumption but may differ from the water distributed by local water utilities in terms of chemical characteristics. The above-mentioned treatment processes remove not only microbiological contaminants in water but also dissolved solids (Kneen *et al.* 2005). As a result, the pH and total dissolved solids (TDS) of other sources of drinking-water is significantly reduced.

All standard values of mandatory parameters shall be applicable to other sources of drinking-water sold by WRS and vending machines except for the standard values of pH and TDS. In order to validate the efficiency of treatment process using RO or distillation, the pH and TDS levels of product water shall be maintained at 5–7 and less than or equal to 10 mg/L, respectively.

CONCLUSIONS AND RECOMMENDATIONS

The updating of the PNSDW is essential for the promotion of water safety in the Philippines. With the recent updates on the water quality parameters, standard values, and methods of analysis as well as new sections on (1) reporting and interpretation of results and corrective actions, (2) emergency drinking-water parameters, (3) proposed SDG parameters, and (4) standards for other drinking-water sources, the updated PNSDW can address the pressing issues and concerns related to the provision of potable drinking-water in the country and the relevant SDG. There are still other activities to be pursued in relation to the PNSDW. These include: (1) comprehensive review of water quality monitoring data from water service providers all over the country, intended for regional standards' formulation and for the improvement of databases of monitoring results and evaluation; (2) increase in the level of awareness and knowledge regarding the updated PNSDW through information dissemination activities for water service providers, regulators, and LGUs; and (3) conduct of researches using the risk-based approach to support the prioritization of water quality parameters.

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REFERENCES

Department of Health 1995 *Implementing Rules and Regulations of Chapter II: Water Supply of the Code on Sanitation of the Philippines*.

Department of Health 2007 *Philippine National Standards for Drinking-Water* [Internet]. Available from: http://www.lwua.gov.ph/downloads_10/Philippine%20National%20Standards%20for%20Drinking%20Water%202007.pdf (accessed 29 November 2015).

Department of Health (DOH) 2011 *Water, Sanitation, and Hygiene (WASH) in Emergencies: Reference Manual*. Health Emergency Management Staff, Manila, Philippines.

Jackson, D. 2015 *Report on Upgrading PNSDW: Risk Based Assessment Workshop*. Prepared for the WHO Training-Workshop on the Principles and Framework of the Risk-based Approach.

Johnston, R. 2015 Sustainable development goals (SDGs). In: *Presented During the Meeting of the Technical Working Group for the Updating of the 2007 Philippine National Standards for Drinking-Water*. College of Public Health, University of the Philippines, Manila, Philippines.

Kneen, B., Lemley, A. & Wagenet, L. 2005 *Reverse Osmosis Treatment of Drinking Water* [Internet]. Available from: http://waterquality.cce.cornell.edu/publications/CCEWQ-04-ReverseOsmosisWtrTrt.pdf.

Magtibay, B., Anarna, M. S. & Fernando, A. 2015 An assessment of drinking-water quality post Haiyan. *Western Pacific Surveillance and Response Journal* **6** (Suppl. 1), 48–52.

National Health and Medical Research Council (NHMRC) of Australia 2011 *Australian Drinking Water Guidelines*. National Health and Medical Research Council, National Resource Management Ministerial Council, Canberra, Australia.

Philippine Statistics Authority (PSA) [Philippines] & ICF International 2014 *Philippines National Demographic and Health Survey 2013*. PSA, Manila, Philippines and ICF International, Rockville, MD, USA.

World Health Organization (WHO) 2002 *Environmental Health in Emergencies and Disasters: A Practical Guide*. World Health Organization, Geneva, Switzerland.

World Health Organization (WHO) 2003 *Heterotrophic Plate Counts and Drinking-Water Safety: The Significance of HPCs for Water Quality and Human Health*. IWA Publishing, London, UK. Available from: http://www.who.int/water_sanitation_health/dwq/HPCFull.pdf (accessed 29 November 2015).

World Health Organization (WHO) 2011 *Guidelines for Drinking-Water Quality,* 4th edn. World Health Organization, Geneva, Switzerland.

World Health Organization (WHO) 2012 *Water, Sanitation and Health: Burden of Disease and Cost-effectiveness Estimates* [Internet]. Available from: http://www.who.int/water_sanitation_health/diseases/burden/en/ (accessed 9 September 2015).

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