Groundwater Quality Analysis of Domestic Water Sources from Hand Dug Wells in Gwallameji, Bauchi

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Abstract — Lack of access to safe and adequate domestic water supplies contributes to poverty levels through the economic costs of poor health and the high proportion of household expenditure on safe water supplies. Gwallameji, a community on the outskirts of Bauchi town has no access to municipal water supply from Bauchi town, groundwater water, mainly hand dug wells are used as domestic water sources. The quality of water available from these hand dug wells in the community were determined by the physical, chemical and biological parameters of the water samples collected from domestic water points in the community. The results from the water samples were compared with World Health Organization (WHO) Standards for Drinking Water. High levels of Nitrate and Chromium above recommended levels from the standard were found in all water samples. Concentrations of Calcium highest value of 213mg/l and Magnesium a highest value of 22.02 mg/l at levels higher than recommended levels for drinking water were also obtained in all samples. It was recommended that restrictions on farming activities with use of fertilizers and location of latrines around domestic water sources should be enforced. Hand dug wells should be at a distance of at least 30m from soak away pits and pit latrines. Well lining and cover should be provided for all hand dug wells to reduce contamination of water from these sources. Increased and continued environmental interventions through public health education by community based health workers, awareness and sensitization campaigns should be carried out for improved household and community sanitation in the area.

Keywords — Domestic water, Groundwater, Water quality.

1 INTRODUCTION

The World Health Organization (WHO) defines domestic water as ‘water used for all usual domestic purposes including drinking, cooking, bathing and washing’ (WHO, 2002). Meeting the daily requirements of quantity must be coupled with quality to ensure a healthy population; Cairncross over years of research found that there is a strong relationship between water quantity, water quality, sanitation and hygiene in protecting and improving health (Cairncross, 1990). Public health is affected by the quantity and quality of water available for use, which also impacts on food security, sanitation, health, employment and other social issues. Adequate access to safe water and proper waste disposal is critical for the well being of a community; therefore potential sources of domestic water supply must be protected to meet standards required.

Groundwater (including spring water), surface water (rivers, streams and ponds) and atmospheric water (rain water, snow and hail) are the main sources of fresh water available for human use. The qualities of these water bodies vary widely depending on the location and environmental factors. Groundwater is referred to as the water that is stored in the pervious, porous and permeable rocks referred to as Aquifer. Water from these sources supplies a large number of communities in need of water for various uses including domestic, agricultural and industrial purposes. The major source of ground water recharge is precipitation that infiltrates the ground and percolates through the soil and pore spaces of rocks. Ground water is not as easily contaminated as surface waters; therefore many communities resort to ground water exploration for domestic water supply in areas where this is accessible. The concept of groundwater pollution is defined by many scholars, Harter (2003) defined ground water pollution as groundwater that has undergone undesirable change in quality which can have adverse effect on human health, therefore; sourcing of safe water for use is paramount in any community. In 2015, the World Health Organization/ United Nations Children’s Fund (WHO/UNICEF) Joint Monitoring Report (WHO/UNICEF, 2015) estimated that 663 million people worldwide still use unimproved drinking water sources and nearly half of all people using unimproved drinking water sources live in sub-Saharan Africa. Nigeria, a sub-Saharan African country is one of the developing countries that are faced with the challenges of improving percentage population having access to improved drinking water sources, the WHO/UNICEF Joint Monitoring Report (WHO/UNICEF, 2014) gives figures for Nigeria as only 64% of the population has access to improved drinking water sources as at 2012.

Lack of sufficient quantity of domestic water supply leads to poor hygiene which may in part be due to lack of access to safe/improved water sources, (Cairncross and Feachem, 1993), this contributes to poverty levels both through the economic costs of poor health and the high proportion of household expenditure on safe water supplies for domestic purposes, the need to purchase water and/or time and energy expended in collection increases hardships. Sourcing of water for domestic use in areas where access to safe water is at a distance greater than 1000m results in women drudgery and increases the possibility of contacting water related diseases. Bradley categorized water related diseases by mode of mode transmission and suggested that there are four principal categories: water-borne - caused through consumption of contaminated water (e.g. diarrhoeal diseases, infectious hepatitis and typhoid); water-washed - caused through the use of inadequate volumes for personal hygiene resulting in skin and eye infections; water-based - where an intermediate aquatic host is required for instance guinea worm disease and schistosomiasis; and, water-
related insect vector - spread through insect vectors associated with water for instance malaria, dengue fever. (Bradley, 1977).

Children bear the greatest health burden associated with poor water and sanitation. Diarrheal diseases attributed to poor water supply, sanitation and hygiene account for 1.73 million deaths each year and contribute over 54 million Disability Adjusted Life Years, a total equivalent to 3.7% of the global burden of disease (WHO, 2002). This place diarrheal disease due to unsafe water, sanitation and hygiene as the 6th highest burden of disease on a global scale, a health burden that is largely preventable (WHO, 2002). Contaminations resulting from poor sanitation greatly impairs water quality, it has been shown that indiscriminate disposal of waste results in organic pollution of water, Lubo used an 18 years historical data to research on a series of organic constituents detected at an unlined landfill, results showed that there had been a substantial concentration of Volatile Organic Compounds found in surrounding surface waters over time (Lubo and Martinez, 2014). Mahesh and Raju showed that data based modeling approaches are needed for development especially in areas where water quality data are limited while high cost of water quality monitoring also does not contribute positively to availability of data, data based modeling approaches are therefore being extensively promoted (Mahesh and Raju, 2012).

Domestic water quality of Gwallameji, a community in Bauchi was analyzed to determine current status of access to safe water and required measures to be taken to meet demand. The quality of water available from these hand dug wells in the community were monitored by the physical, chemical and biological parameters of the water samples collected from water points in the community. Results obtained were used to determine the safety levels of the water sources, water parameters that need to be addressed in moving the community forward towards achieving sustainable safe water sources were identified. The research focused on:

• Assessing the water quality from some domestic water sources used in Gwallameji Community in Bauchi State.
• Determining the factors affecting the quality from sources used.

2 RESEARCH METHODOLOGY

Bauchi town is the Capital of Bauchi State located in the North Eastern part of Nigeria. Gwallameji community is about 10 kilometers from the centre of Bauchi town and it is located between longitudes 9°45′E and 9°55′E and latitudes 10°15′N and 10°20′N. Gwallameji has a population of about 800 people, majority of whom are farmers. The community has no access to municipal water supply, groundwater, mainly hand dug wells are used as domestic water sources.

The geological formation of Bauchi State is composed of crystalline basement complex made up of coarse foliated granite of the older granite suite formation and of Palaeozoic age geological activities, the basement complex is favorable for groundwater storage and the groundwater is being accessed through boreholes and hand dug wells for domestic use. From the total number of hand dug wells in Gwallameji community, a representative number of sampling points were identified for this research and of these water sources, ten points were selected by stratified sampling, derived by diving the community into zones and locations shown by the Global Positioning System (GPS) locations, thereafter, sampling points were randomly selected from each zone. The GPS instrument was used to determine the geographical location of all sampled well, each sampling point was identified using codes signifying the hand dug well number.

Water samples were collected from the representative locations of the water sources from which members of the community obtain domestic water. Three samples were collected from each selected hand dug well in sterilized sampling bottles which were labeled by the given sampling codes and transported to the laboratory for analysis. Laboratory experiments were carried out using the Standard Methods for Examination of Water and Wastewater (APHA, 1998). World Health Organization (WHO) Drinking Water Standards (WHO, 1971) was used to compare water quality results with Standards. This research was carried out between March, 2014 and January, 2015. Physical, Chemical and Biological water quality parameters were determined as detailed below:

Physical parameters: The following physical parameters were determined in the laboratory: Turbidity, Color, Total dissolved solids (TDS). Taste and odor were observed. Temperature recorded only gave laboratory values during experiment and not field values.

Chemical Parameters: pH, Magnesium, Calcium, Cadmium, Chloride, Manganese, Chromium, Iron, Lead, Nitrate, Sulphate, Fluoride, Nitrate, Nitrite.

Microbiological Parameters -Total Bacterial Count.
3 RESULTS AND DISCUSSIONS

3.1 Results
Results obtained from the research are presented in Tables 1 to 4 and Figures 2 and 3. Three samples were collected from each water source and mean values are presented for each parameter.

3.1.1 Identification Parameters
Table 1 presents the identification parameter for the Hand Dug Wells (HDW) selected for the research.

Table 1 – Coding for Selected Hand Dug Well and Global Positioning System (GPS) Information

| Hand Dug Well (HDW) Number | Sampling Code | GPS Location       |
|----------------------------|---------------|--------------------|
| 1                          | HDW 1         | N10.15548° E 009.47995° |
| 2                          | HDW 2         | N10.15391° E 009.47859° |
| 3                          | HDW 3         | N10.15225° E 009.47604° |
| 4                          | HDW 4         | N10.15805° E 009.48114° |
| 5                          | HDW 5         | N10.15652° E 009.47905° |
| 6                          | HDW 6         | N10.15370° E 009.47486° |
| 7                          | HDW 7         | N10.15484° E 009.49209° |
| 8                          | HDW 8         | N10.15497° E 009.49420° |
| 9                          | HDW 9         | N10.15587° E 009.48170° |
| 10                         | HDW 10        | N10.15805° E 009.48089° |

3.1.2 Physical Parameters
Table 2 shows the laboratory results of Physical parameters monitored. Temperature of samples on the field was not obtained; parameters monitored in the laboratory are presented.

3.1.3 Chemical Parameters
Results of Chemical parameters are presented in Table 3 and in Figures 2 and 3. Table 3 showed values obtained in water samples for pH, Magnesium, Chloride, Sulphate, Calcium, Fluoride, Cadmium, and Lead.

4 ANALYSIS OF RESULTS

4.1 Analysis of Physical Parameters:
Table 2 shows that from the result obtained, 80% of the water samples had objectionable taste; the WHO standards stipulated that water for domestic use must be unobjectionable. Color (Hazen Unit) of water samples were below the stipulated requirement of WHO which is 15. The result obtained for Turbidity (NTU) indicated that all the water samples taken were within the WHO standards of 5 NTU. Total dissolved solid (TDS mg/l) show that only the water sample from HDW3 with a value of 595mg/l was observed to be above the stipulated WHO standards of 500mg/l.

4.2 Analysis of Chemical Parameters
From Table 3, pH values obtained indicated that all the water samples were within the stipulated WHO standards of 6.5 – 8.5 for drinking water. Magnesium in sufficient quantity impacts bitter taste in water, the result indicated that all the water samples were above the stipulated WHO standards value of 0.20mg/l. Chlorides generally are present in groundwater as sodium chloride or calcium chloride. Concentrations greater than about 250 mg/l usually cause the water to taste ‘salty’, from the results obtained all the water samples were within the stipulated WHO standard value of 250mg/l for Chloride.

Sulphate result indicated that 20% of the samples were above the stipulated WHO standards value of 250mg/l. Sulphate is generally present in groundwater in one of three forms: as magnesium sulphate, sometimes called Epsom salt; as sodium sulphate called Glauber’s salt; or as calcium sulphate called gypsum. Water with a high sulphate concentration has a medicinal taste and a pronounced laxative effect on those not accustomed to it. Sulphate also occurs in earth materials in a soluble form that is the source for natural concentrations of this compound. Man-made sources similar to those for chlorides also can contribute to sulphate concentrations locally as are industrial wastes.

Calcium results indicated that all the water samples were within the stipulated WHO standard value of 200mg/l except for water sample from HDW7 which had a high value of 213mg/l. Calcium ions are present in all natural water and are often refer to as hardness factor. Hardness is the ability of water to cause precipitation of insoluble calcium salt of higher fatty acid from soap solutions.

Fluoride in drinking water has been shown to be associated with the occurrence of both dental cavities and mottled tooth enamel or dental fluorosis. The amount of dental cavities decreases as fluoride concentrations increase, but above concentrations of 1.0 mg/l, the incidence of fluorosis or darkened and mottled teeth increases. From the result obtained, all the water samples were observed to be within the stipulated WHO standards value of 1.5mg/l. Cadmium results obtained showed that the water samples had a zero containment level. Concentrations of cadmium higher than 0.003mg/l can be very toxic to the kidney.

Lead, (mg/l): From the result obtained, the water samples had a zero containment level of lead concentration. Presence of lead in large quantity might cause cancer, interference with vitamin D metabolism and affects mental development in infants as well as toxic to the central and peripheral nervous systems.
Table 2 – Results of Physical Parameters of Water Samples

|    | HDW1 | HDW 2 | HDW3 | HDW4 | HDW5 | HDW6 | HDW7 | HDW8 | HDW9 | HDW10 |       |
|----|------|-------|------|------|------|------|------|------|------|-------|--------|
| Temp (°C) | 28.15 | 28.2 | 28.1 | 28.25 | 28   | 28.35 | 28.2 | 28.35 | 28.15 | 28.4 | Ambient |
| Color (Hazen unit) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |        |
| Turbidity (NTU) | 2 | 1.5 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 5 |        |
| Taste and Odor | Unobjectionable | Unobjectionable | Objectible | Objectible | Objectible | Objectible | Objectible | Objectible | Objectible | Unobjectionable |        |
| TDS (mg/l) | 216 | 436 | 595 | 288 | 326 | 455 | 296 | 320 | 379 | 271 | 500 |

Table 3 – Results of Chemical Parameters—pH, Magnesium, Chloride, Sulphate, Calcium, Fluoride, Cadmium, and Lead found in Water Samples

|    | HDW1 | HDW 2 | HDW3 | HDW4 | HDW5 | HDW6 | HDW7 | HDW8 | HDW9 | HDW10 | WHO |
|----|------|-------|------|------|------|------|------|------|------|-------|-----|
| pH | 6.9  | 6.4  | 6.35 | 6.35 | 6.9  | 6.4  | 6.5  | 6.25 | 6.5  | 6.4  | 6.5-8.5 |
| MAGNESIUM, (Mg/l) | 12.42 | 10.52 | 10.58 | 11.17 | 10.12 | 10.42 | 22.02 | 10.22 | 10.66 | 11.24 | 0.2 |
| CHLORIDE, (Mg/l) | 64.98 | 201 | 209.9 | 131.43 | 157.84 | 97.87 | 125 | 154.97 | 82.17 | 250 |
| SULPHATE, (Mg/l) | 90 | 241 | 260 | 101 | 129 | 290 | 70 | 81 | 189 | 109 | 250 |
| CALCIUM, (Mg/l) | 190 | 142.5 | 168.5 | 176 | 179 | 192 | 213 | 161 | 193 | 104 | 200 |
| FLUORIDE, (Mg/l) | 0.1 | 0.2 | 0.5 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 1.5 |        |
| CADMIUM, (Mg/l) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.003 |
| LEAD, (Mg/l) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.001 |

Figure 2 gives the results obtained for Nitrite and Nitrate. Nitrite results showed that all the water samples were observed to be below the stipulated WHO standard value of 3mg/l. Nitrate results show that all the samples were observed to be above the stipulated WHO standards value of 50mg/l. Very high concentration of nitrate in water is potentially hazardous causing a disease called Asphyxia (blue-baby syndrome) in infants under 3 months. Kapoor and Viraraghavan (1997) carried out a research on Nitrate concentrations in surface and ground water, trend analysis showed that Nitrate values can consistently increase over the years for the water sources if practices in environment are not reversed. Several treatment processes including ion exchange, biological denitrification, chemical denitrification, reverse osmosis, electrodialysis, and catalytic denitrification can remove nitrates from water with varying degrees of efficiency, cost, and ease of operation. Jingtao et al (2015) showed that nitrification of Nitrogen containing materials plays an important role in assimilation of nutrients in particular surrounding environment.

Figure 3 presents the results obtained for Manganese, Chromium and Iron in Water Samples. From the result, all the water samples were observed to be within the stipulated WHO standards of 0.5mg/l for Manganese.
Manganese in groundwater occurs in soluble state and when exposed to air, oxidizes causing brownish or black stains on laundry. The stains caused by manganese generally are harder to remove than those caused by iron. Manganese normally occurs in low concentrations, but even then a slimy substance can contribute to the clogging of water pipes and in high concentration can cause Neurological disorder.

Chromium, (mg/l): The results obtained indicated that all the water samples were above the stipulated WHO standards of 0.05mg/l. This can be due to the presence of Chromium compounds in domestic waste, from various synthetic materials, through waste incineration and other treatment processes, Chromium may spread to the environment via leakage or improper disposal practices. These compounds percolate deep through soil and subsoil causing extensive pollution of streams, creeks and water wells, direct ingress of leachate affects the quality of groundwater (Ojoawo and Onyemoabi, 2007).

Iron, (mg/l): Dissolved iron, although not harmful to human health does adversely impact some aesthetic qualities of potable water e.g. taste and color. Most groundwater in Nigeria have iron and it manifest as rusty brown color, stale metallic taste in severe cases and brown stain in bath tubs and kitchen sinks compounding this problem; dissolved iron impact deep reddish brown color and slightly bitter taste in water. WHO guidelines give a value of 0.3mg/l for drinking water and from the result obtained, it can be seen that all the samples are within the WHO guidelines.

4.3 Analysis of Biological Parameters:
Table 4 presents the results of Total Bacterial Count, (cfu/100ml): From the result obtained, the water samples were observed with values above the stipulated WHO standards of zero bacteria contaminant level except for water sample from HDW7 which is within the stipulated WHO standards of zero bacteria containment level. Sanitary Risk Assessment research in a similar location had shown that all of the hand-dug wells (HDWs) monitored were at risk, identified sources of pollution are sanitation facilities within 10m of the HDWs with lack of adequate apron around well head and, possible contamination from abstraction method (Ndububa, 2015).

| PARAmeter | HDW 1 | HDW 2 | HDW 3 | HDW 4 | HDW 5 | WHO |
|-----------|-------|-------|-------|-------|-------|-----|
| BacTera count (cfu/100ml) | 2 | 1 | 2 | 2 | 3 | - |
| PARAmeter | HDW 6 | HDW 7 | HDW 8 | HDW 9 | HDW 10 | WHO |
| BacTera count (cfu/100ml) | 1 | 0 | 1 | 3 | 5 | - |

5 Conclusion
Results show that Gwallameji community’s domestic water supply does not meet drinking water standards in some of the parameters monitored, it is therefore concluded that:

1. High levels of Chromium recorded show the need for further research to determine the source of generation for this chemical contaminant.
2. Magnesium was found in all the samples taken. This suggests the presence of Dolomite in the community; further research is required to ascertain this.
3. High levels of nitrate can be from fertilizers, septic systems or leaking sewage and organic fertilizer or manure applied to agricultural fields. Majority of residents are farmers and farming activities in the environment could have contaminated ground water sources.
4. The presence of bacteria in domestic water at any level is not acceptable as this is an indication of pollution, actions should be taken to prevent or remove contaminants from these water sources.
5. High concentration of Calcium and Magnesium contaminations which results to the bitterness and high level of hardness were found in the water samples in the study area.

6 Recommendations
1. High levels of Nitrogen Nitrate in water samples which are possibly from use of fertilizers from farming activities and domestic waste may be reduced to acceptable limits by enforcing restrictions on farming activities around residences and location of latrines around domestic water sources. Hand dug wells should be at a distance of at least 30m from possible leachate and seepage leaks from soak away and pit latrines as stipulated by WHO.
2. Well lining and cover should be provided for all hand dug wells to prevent contamination of water.
3. Groundwater sources used in Gwallameji should be regularly treated by method of chlorination to eliminate harmful organisms.
4. It is recommended that increased and continued environmental interventions through public health education by community based health workers, awareness and sensitization campaigns needs to be carried out for improved household and community sanitation in the rural areas.
5. Boiling and filtering of water before drinking will eliminate pathogenic micro-organisms in drinking water, it is therefore recommended that members of the community should practice this household water treatment option.

References
APHA. (1998). Standard Methods for the Examination of Water and Wastewater. Washington DC: American Public Health Association.
Balogun, V. A., Aramcharoen, A., Mativenga, P. T., & Chuan, S. K. (2013). Impact of Machine Tools on the Direct Energy and Associated Carbon Emissions for a Standardized NC Toolpath Re-engineering Manufacturing for Sustainability (pp. 197-202); Springer.
Balogun, V. A., Kirkwood, N. D., & Mativenga, P. T. (2014). Direct Electrical Energy Demand in Fused Deposition Modelling. Procedia
CIRP, 15, 38-43.
Balogun, V. A., & Mativenga, P. T. (2013). Modelling of direct energy requirements in mechanical machining processes. Journal of Cleaner Production, 41, 179-186.
Bradley D. (1977). Health aspects of water supplies in tropical countries: Water, wastes and health in hot climates. John Wiley and Sons, Chichester, UK, pp 3-17.
Cairncross A. M. (1990). Health impacts in developing countries: new evidence and new prospects, Journal of the Institution of Water and Environmental Management, 4(6): 571-577.
Cairncross S and Feachem R. (1993). Environmental Health Engineering in the Tropics: an Introductory Text, 2nd Edition John Wiley and Sons, Chichester, UK.
Carter R C, Tyrrel S F and Howsam P. (1997). The impact and sustainability of water and sanitation programmes in developing countries. Journal of the Chartered Institution of Water and Environmental Management, 13: 292-296
Chen, L., Hoey, J., Nugent, C. D., Cook, D. J., & Yu, Z. (2012). Sensor-based activity recognition. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 42(6), 790-808.
Harter, T. (2003). Groundwater quality and groundwater pollution. A Text Note from - Division of Agriculture and Natural Resources (ANR), University of California:
http://anrcatalog.ucanr.edu/pdf/8084.pdf
Ishola, A. O., Laoye, B. J., Olatunji, B. P., Bankole, O. O., Shallie, P. D., & Ogundele, O. M. (2016). Neural and behavioural changes in male periadolescent mice after prolonged nicotine-MDMA treatment. Metabolic brain disease, 31(1), 93-107.
Jingtao Ding, Beidou Xi, Qigong Xu, Jing Su, Shouliang Huo, Hongliang Liu, Yijun Yu, Yanbo Zhang (2015) Assessment of the sources and transformations of nitrogen in a plain river network region using a stable isotope approach. Journal of Environmental Sciences, Volume 30, 1 April 2015, Pages 198-206.
www.journals.elsevier.com/journal-of-environmental-sciences
Kapoor, A. and Viraraghavan, T. (1997). "Nitrate Removal From Drinking Water—Review." Journal of Environmental Engineering., Vol. 123, No. 4 pp. 371-380 (ASCE).
Kong, D., Choi, S., Yasui, Y., Pavanaskar, S., Dornfeld, D., & Wright, P. (2011). Software-based tool path evaluation for environmental sustainability. Journal of Manufacturing Systems, 30(4), 241-247. doi: 10.1016/j.jmsy.2011.08.005
Lubo, Liu and Martinez, A. (2014). Investigation of the Migration of Selected Volatile Organic Compounds in Groundwater under an Unlined Landfill. Energy and Environmental Engineering Journal, 2, 55 - 66. www.hrpub.org
Mahesh Kumar and Raju, B.S. N. (2012). Time Series Forecasting of Water Quality of Godavari River. International Organization of Scientific Research, Journal of Mechanical and Civil Engineering (IOSR – JMCE). Volume 1, Issue 1, Pages 39 – 44.
www.iosrjournals.org/iosr-jmce
Ndububa, O. I. and Idowu, T. J. (2015) Sanitary Risk Assessment of Domestic Hand-dug Wells in Yelwa-Tudu, Bauchi, Nigeria. International Research Journal of Public and Environmental Health. Volume 2(8) pp102 - 111. www.journalissues.org/irjpeh
Ojoaowo S. O and Onyemoabi, S (2007). Environmental Implication of a Municipal Solid Waste Dumpsite Leachate in Contiguous Well. International Journal of Environmental issues. Vol. 5, No 1&2.
WHO. (1971). Guidelines for Drinking Water Quality, 3rd Edition, Volume 1. Geneva: World Health Organization. www.who.org
WHO, UNICEF (2014). Progress on Drinking Water and Sanitation Update. . New York: Joint Monitoring Report, World Health Organization/ United Nations Children's Fund. www.who.org
WHO, UNICEF (2015). Progress on Sanitation and Drinking Water, Joint Monitoring Report. Geneva: World Health Organization/ United Nations Children's Fund. www.who.org
Young, J., Roy, H. S., & Young, J. (2007). Transforming server-side processing grammars: Google Patents.