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From vision to action
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Tools of implementation to deal with water quality: Governments' roles and challenges

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1. Introduction

Ambient water quality is a key element in defining both the utility of water for human consumption and the health of water ecosystems used for drinking, irrigation and recreation.

Quick facts

- Gastrointestinal infection causes 2.2million deaths per year, mostly young children in developing countries[1]
- Some 4% of deaths and 5% of health impairments are caused by the 4 billion cases of Diarrhoea per year world-wide which is indicative of poor water quality and sanitation[1].
- Chemical contamination of groundwaters with, largely geogenic, arsenic, present further human health risks principally in developing countries[2] with 35-77 million people in Bangladesh at risk of Arsenic contamination[3].
- Agricultural pesticides also have been linked to cancer incidence, foetal deformity, pulmonary and haematological morbidity and immune system deficiencies over broad regions[4].
- Increasing eutrophication of fresh and near-shore waters has been the cause of hepatotoxin, neurotoxins and dermatotoxins exposures of swimmers and water consumers world-wide in recent years[5]. Marine water pose significant risks from diarrhoeic shellfish poisoning (DSP); amnesic shellfish poisoning (ASP), neurotoxic shellfish poisoning (NSP) and Venerupin shellfish poisoning (VSP)[6] with high fatality rates in affected populations.

2. Commitment to progress in Water Quality

In July 2014, the Open Working Group on Sustainable Development Goals (SDGs) proposed a number of global goals of direct relevance to water quality[7]:

1 http://www.who.int/water_sanitation_health/diseases/diarrhoea/en/
2 http://www.who.int/water_sanitation_health/dwq/arsenic/en/
3 http://www.who.int/docstore/bulletin/pdf/2000/issue9/bu0751.pdf?ua=1
4 http://www.fao.org/docrep/w2598e/w2598e07.htm#human health effects of pesticides
5 http://ec.europa.eu/environment/water/water-nitrates/pdf/eutrophication.pdf
6 http://www.rightdiagnosis.com/v/venerupin_shellfish_poisoning/intro.htm
7 Anon (2014a) Open Working Group Proposal for Sustainable Development Goals. Summary Report. 24p. http://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=1579&menu=1300

Goal 6. Ensure availability and sustainable management of water and sanitation for all

- *6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all.*
- *6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.*
- *6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and increasing recycling and safe reuse by [x] per cent globally.*
- *6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.*
- *6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.*
- *6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.*
- *6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.*
- *6.b Support and strengthen the participation of local communities in improving water and sanitation management*

Target 6.3 is the most focused on water quality. However, good water quality is an essential requirement, or the required outcome, for most of the Goal 6 targets: i.e.

- provision of 'safe' drinking water (6.1) implies good water quality;
- provision of hygiene for all (6.2) requires a sufficiency of clean water for washing;
- water use efficiency and sustainable withdrawals (6.4) maintains healthy ecosystems able to operate as sustainable receiving environments for human waste streams;
- integrated water resource management (6.5) includes water quality maintenance; and
- ecosystem protection and restoration (6.6) is founded on adequate water quality to maintain ecosystem health.

2. Challenges and policies

Investment and financing

The fact that water quality has, to date, been somewhat neglected by the international agencies has been noted as follows[8]:

[8] Anon (2014b) *A Post-2015 Global Goal for Water: Synthesis of key findings and recommendations*. UN Water. 41p.

'To date, these aspects of water management have received less attention than they need, consequently in many places the action will start from a very low base. For this reason, the level of ambition has been limited and should be considered a minimum starting point. Many countries will be in a position to take a more ambitious approach.'

Ambient water quality improvement, particularly through nutrient and eutrophication reduction, is also a means of producing sustainable ecosystem services (often termed 'environmental capital');

'*Additional and important health benefits also result from positive impacts on the environment. These include improved water quality in rivers and lakes since decreased eutrophication of freshwater and coastal areas improves ecosystem functioning in these areas and, by extension, provides improvements in ecosystem services that support beneficial social and economic activities*.'

The key outcomes of this target are listed as[7]:

(i) *public health protection;*
(ii) *protection of the environment;*
(iii) *promote the reuse of wastewater and sludge; and*
(iv) *support the multiple opportunities of water, nutrient and energy recovery.*

Delivery of the water quality information needed to chart progress on these goals is likely to involve considerable new investment, principally, to fill gaps for data poor regions. Existing initiatives designed to build water quality data holdings have been initiated, principally seen in GEMS Water and the GEMStat data repository[9]. However, a recurring theme and comment by GEMS Water team members is the heterogeneous coverage and quality of the present empirical evidence in GEMStat which is needed to make global water quality assessments. At a GEMS Water workshop on global water resource modelling in Saskatoon, Canada: Silva et al. (2010)[10] noted;

'*Unfortunately, there is a complete disconnect between the reporting conducted and the level of data needed for accurate assessments*.'

GEMStat has sought to rectify this deficiency by more proactive data acquisition, the 2005 Environmental Sustainability Index (ESI) report noted the effects of this approach and stated;

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http://www.un.org/waterforlifedecade/pdf/27_01_2014_un-water_paper_on_a_post2015_global_goal_for_water.pdf

[9] GEMStat was launched on World Water Day, March 22nd 2005, to help kick-off the 'Decade for Action: Water for Life.'

[10] Silva, G., Dube, M. and Robarts, R. (2010) Workshop on Global Water Quality Modelling, October 13th and 14th, The National Hydrology Research Centre (NHRC), Saskatoon, SK, Canada. http://www.unep.org/gemswater/Portals/24154/common/pdfs/modelling_workshop-final_report.pdf

As a result of these changes, participation in GEMS Water has grown from less than 40 countries when the ESI first started using the data to over 100 countries today, although data coverage is still low[11]*.*

Similar concerns have been expressed by those assessing the utility and practicality of accounting the natural capital represented by water quality maintenance within an ecosystem framework. For example Russi and Brink (2013)[12] note the lack of harmonised monitoring data available in the summary statement:

> '*Many challenges remain in developing water quality accounts, including methodological development, terminology, data collection, systematisation and sustained production of the accounts'.*

Implementing appropriate technologies

The technologies for water quality data acquisition are well established and implemented world-wide. Scope exists for deployment of remote sensing tools such as satellite imagery which has been successfully utilised to identify algal blooms over broad areas. However physical sampling of a core indicator set is likely to be needed into the foreseeable future if the water quality drivers of adverse ecological or public health conditions are to be measured and their related impairments predicted in time for appropriate public health warnings to be delivered. There are interesting developments in real-time measurement technologies through the deployment of portable sondes which are rapidly becoming available. However, equivalence of in-situ and laboratory measurements is essential in this regard and international standards and full AQC should, whenever possible, be built into sampling and data acquisition protocols.

Improving capacity

The Rio+20 outcome document emphasizes the need for enhanced capacity-building for sustainable water quality improvement through[13].

> *…………. efforts to increase and improve effectiveness and efficiency of financing of basic services and water resources management; to improve capacity building and engage stakeholders; and to establish mechanisms for development and sharing of water technologies.*

Improving water governance

[11] http://www.unep.org/gemswater/Portals/24154/publications/pdfs/technical_advisory_paper3.pdf

[12] Russi, D. and ten Brink, P. (2013) Natural Capital Accounting and Water Quality: Commitments, Benefits, Needs and Progress. A Briefing Note. The Economics of Ecosystems and Biodiversity (TEEB). http://www.zaragoza.es/contenidos/medioambiente/onu/1315-eng_Natural_Capital_Accounting_and_Water_Quality_Commitments_Benefits_Needs_and_Progress.pdf

[13] http://www.uncsd2012.org/content/documents/231Water%20for%20posting.pdf

The development of a central water quality data resource is aligned with the UN Water Strategy 2014-2020 which states[14]:

> *UN-Water has access to key data, information and reporting on policies related to water. UN-Water thus aims to be the first point of contact when stakeholders at all levels require the most up-to-date thinking on water related issues, channelling inquiries to the relevant UN-Water Members or Partners where appropriate. UN-Water also plays a significant role in monitoring progress towards internationally agreed goals and targets. The knowledge hub on water related issues, thus created by UN-Water, is a vital global public good that needs the support of all UN-Water entities and stakeholders if it is to reach its maximum potential.*

3. Tools and case studies

GEMS Water

Within GEMS Water, there have been separate efforts to assess the feasibility of applying the GEMStat[15] database to deliver water quality index (WQI) development. Several useful documents have emerged from GEMS Water activities and a recurring theme and comment by GEMS team members is the heterogeneous coverage and quality of the empirical evidence in GEMStat which is needed to make global water quality assessments or to underpin a globally applicable index development. At a GEMS Water workshop on global water resource modelling in Saskatoon, Canada: Silva et al. (2010) noted;

> '*Unfortunately, there is a complete disconnect between the reporting conducted and the level of data needed for accurate assessments*.'

This patchy coverage in available data is seen in the GEMStat pathogens data base available for download which covers only US water utilities in its present form[16]. GEMS Water has noted this weakness in the empirical data coverage in many reports and the issue has been addressed by its Technical Advisory Groups[17]. GEMStat has sought to rectify this deficiency by more proactive data acquisition, the 2005 Environmental Sustainability Index (ESI) report noted the effects of this approach and stated;

> *As a result of these changes, participation in GEMS Water has grown from less than 40 countries when the ESI first started using the data to over 100 countries today, although data coverage is still low.*

See UNEP GEMS Water Technical Advisory paper No 3 Sept 2006, Page 7[18]

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[14] http://www.unwater.org/fileadmin/user_upload/unwater_new/docs/UN-Water_Strategy_2014-2020.pdf.

[15] GEMStat was launched on World Water Day, March 22nd 2005, to help kick-off the 'Decade for Action: Water for Life.'

[16] Accessed 17th August 2014 http://www.unep.org/gemswater/FreshwaterAssessments/PathogensProject/tabid/78261/Default.aspx

[17] See the note of the 3rd Technical Advisory Group on water quality September 2006 http://www.unep.org/gemswater/Portals/24154/publications/pdfs/technical_advisory_paper3.pdf

[18] http://www.unep.org/gemswater/Portals/24154/publications/pdfs/technical_advisory_paper3.pdf

However, the present GEMS www site notes the continued data heterogeneity and urges caution where these data are used for water quality index calculations.

> *The WQI calculations are based on water quality data currently housed in GEMStat only. For some participating countries, data may have a limited geographic representation and / or temporal coverage. Therefore, results must be carefully assessed.*
>
> http://www.gemstat.org/waterqualityindexguide.aspx

Similar concerns have been expressed by those assessing the utility and practicality of accounting the natural capital represented by water quality maintenance within an ecosystem framework. For example Russi and Brink (2013) note the lack of harmonised data available in the summary statement:

> '*Many challenges remain in developing water quality accounts, including methodological development, terminology, data collection, systematisation and sustained production of the accounts'.*

Other global attempts at modelling water stress to derive indicator systems by the academic community, discussed in Silva et al. (2010), e.g. Vorosmarty et al. (2010), have not used water quality 'ground truth' data to validate their model predictions. Rather, they have employed other modelled assessments as their validation benchmark for water quality parameters. For example, in the case of catchment phosphorus output, Vorosmarty et al. (2010) compared their predictions with earlier model outputs by Harrison et al. (2005) for this purpose[19]. This type of modelled indicator generation is a useful tool to fill data gaps but it is not based on empirical observation simply because of the problems of data availability for significant areas noted above.

Water Quality Index development[20]

Examples of water quality index development and use can be seen in many countries including Brazil[21], Colombia, and Canada. The Colombian approach[22] defines four indices for different water uses with specific parameter sets for each use class outlined in Table 2. Implementation is via the country's Environmental Information System (SIA) administered by the Ministry of Environment and Sustainable Development who are responsible for monitoring the indicators for different water bodies outlined in Table 1. The Institute for Marine and Coastal Research (INVEMAR) conducts parallel monitoring of marine and coastal water quality[23].

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[19] This is described in the Supplementary Documentation accessed from the Nature www site 17/08/2014 http://www.nature.com/nature/journal/v467/n7315/full/nature09440.html#supplementary-information

[20] This section is taken partly from the Ambient Water Quality Task Team report to the Nairobi meeting on '*Development of a coherent monitoring framework for post-2015 water targets'* UNEP/WHO/UN-HABITT

[21] http://apps.unep.org/publications/pmtdocuments/PanoramaAguasSuperficiaisIngles.pdf

[22] https://www.siac.gov.co/contenido/contenido.aspx?catID=815&conID=1347

[23] http://www.invemar.org.co/ingles/noticias.jsp?id=4270

Table 1 Water quality parameters used for the four water quality indicators and use categories used in the Colombian system

Indices	Impact [I]/ User [U]	Parameters
Water Quality Index (WQI) (for surface)	I,U	COD, total suspended solids, DO, pH, conductivity
Index on potential water quality alteration (to evidence potential water quality alteration from pollution load pressure exerted different sectoral activities)	I	water availability, COD, BOD, total suspended solids, N-tot, P-tot
Marine and Estuary Water Quality Index	I,U	DO, pH, salinity, nitrite/nitrate, ortho-phosphate, suspended solids, dissolved and dispersed petroleum hydrocarbons, total organochlorine, heavy metals (Cd, Cr and Pb), total and thermo-tolerant coliforms
Coastal Bathing Water Quality Index	U	total coliform, faecal coliform

The National Water Agency of Brazil is also applying indices for national water quality monitoring[24] (see Table 2). The Brazilian Water Quality Index approach was developed in 1970s in the United States by the National Sanitation Foundation. From 1975, the approach was used by Cetesb (the São Paulo Environment Agency). In the following decades, other Brazilian states have adopted this integrated quality index (IQA), which today is the main index of water quality used in the country. The parameters used in the calculation of the IQA are mostly indicators of contamination caused by the release of domestic sewage. This index does not address several important parameters for public water supplies, such as toxic substances (e.g. heavy metals, pesticides, organic compounds), pathogenic protozoa and substances that affect the organoleptic characteristics of water.

The IQA requires nine parameters with their respective weights [25] (Table 2, and see 'w' in equation (1)) which are used to calculate the index for 7 water use categories in Table 3. The site quality values are calculated using formula (1) below. The WQI values are categorized into ranges that vary among Brazilian states (see Table 4 below).

$$IQA = \prod_{i=1}^{n} q_i^{w_i} \quad \text{...} (1)$$

[24] http://pnqa.ana.gov.br/Estrutura/Inicio.aspx
[25] http://pnqa.ana.gov.br/IndicadoresQA/IndiceQA.aspx

The value of ‘q’ in equation (1) is derived from a series of parameter specific graphs as exemplified in Figure 1.

Table 2 Parameter weights used in the Brazilian WQI system

Parameters	Weight
DO	0,17
Termotolerant Coliforms	0,15
pH	0,12
BOD	0,10
Temp	0,10
N-tot	0,10
P-tot	0,10
Turbidity	0,08
Total solids	0,08

Table 3 Water use categories and associated parameters used for indicator development in Brazil

Indices	Impact [I]/ User [U]	Parameters
Water Quality Index (WQI) – see qualification below	I,U	DO, thermo-tolerant coliforms, pH, BOD, temperature, N-tot, P-tot, turbidity, TSS
Raw water quality index for public water supply	U	This index is composed of three groups of parameters: - WQI - parameters that evaluate the presence of toxic substances (mutagenicity test, potential formation of trihalomethanes, lead, cadmium, total chromium, mercury and nickel) - parameters that affect the organoleptic quality of the water (phenols, iron, manganese, aluminium, copper and zinc)
Trophic state	I	P-tot; different classification in rivers and reservoirs, respectively
Toxic contamination	I,U	ammonia, total arsenic, total barium, total cadmium, total lead, free cyanide, total copper, dissolved copper, hexavalent chromium, total chromium, total phenols, total mercury, nitrites, nitrates and total zinc. Concentrations are derived from the national water quality guidelines.
Bathing water quality	U	faecal coliform (thermo-tolerant), *E. coli*, enterococci
Aquatic life protection	U	This index is composed of two sub-indices: (i) Minimum index parameters for aquatic life protection, including substances that cause toxic effect on aquatic organisms besides pH and dissolved oxygen. (ii) The trophic state index.
Reservoir water quality (to check the degradation of water quality in the reservoirs)	U	Dissolved Oxygen Deficit, Chlorophyll-a, P-tot, secchi depth, COD, Inorganic-N, retention time, Cyanobacteria, average depth

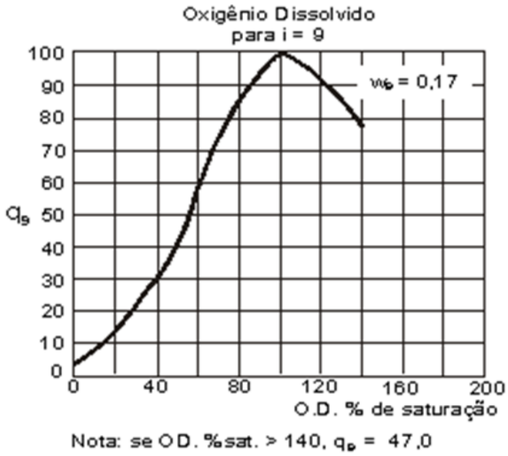


Figure 1 Derivation of 'q' values for equation (1) for each parameter in the Brazilian water quality index.

Using this approach, surface waters are divided into 5 categories with different threshold values for different Brazilian states (see Table 4).

Table 4 Water quality classes derived from the Brazilian water quality index used in different states

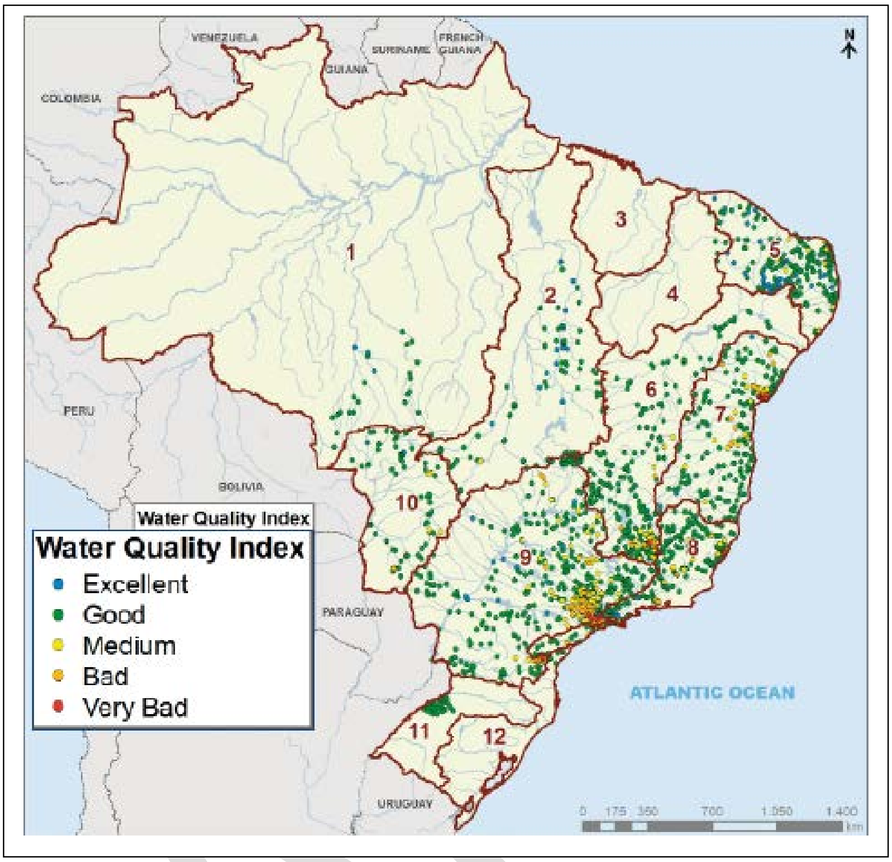
WQI ranges used by the following states: AL, MG, MT, PR, RJ, RN, RS	WQI ranges used by the following states: BA, CE, ES, GO, MS, PB, PE, SP	Water quality assessment
91-100	80-100	Excellent
71-90	52-79	Good
51-70	-51	Moderate
26-50	20-36	Poor
0-25	0-19	Very poor

The outcomes of the Brazilian water quality index system were presented at World Water Week in Stockholm by Mercelo Pires da Costa in September 2014 (Figure 2[26])

[26] http://programme.worldwaterweek.org/sites/default/files/presentation_seminar_marcelo_costa_final_version.pdf

Figure 2
Site classifications in the Brazilian water quality index

Source:- Marcelo Pires da Costa, World Water Week, Stockholm 2014



Case Studies

Korea

- **Issues Addressed**
  - **Water supply access gap: i.e. rural/urban**
  - **Discharge water quality standard**
    - N and P pollution of lakes evident
    - Emerging issue of endocrine disrupters
  - **Nonpoint source control**
    - Driver of most pollution incidents
    - Storm-water is a major cause
- **Policy Response**
  - **National Water Environment Master Management Plan in 2006**
    - measures to achieve the water quality improvement goals.
  - **Collaborative plans between departments for diffuse pollution**
    - eco-friendly farming policy in 2004
  - **water supply and sanitation in rural areas**
    - 10-year strategy on service access rate for.
  - **National Water Reuse Master Plan in 2010**
    - annual reuse targets established for 2020
  - **Consolidation of water and wastewater management**
    - improve the efficiency of services operations
  - **Enforcing water quality regulation and monitoring**
    - Enforcing the criteria on the sewage effluent limitation
    - Establishing annual national monitoring plans
    - A real-time remote water quality monitoring system (Sooshiro) in 740 sewage and waste water treatment plants
    - Public Reporting water quality data through the web-based Water Environment Information System, and data collected from 762 sites (573 sites of rivers and streams and 189 sites of lakes and ponds)
  - **Developing integrated river basin management system**
    - Introduction the reporting system and control zone for diffused sources control (Apr, 2006),
    - Total Water Pollution Load Management System
    - Introduction the reporting system and control zone for diffused sources control
    - Designation of Riparian Buffer Zones
    - Water Use Charges & River Basin Management Fund.
- **Key Lessons**
  - **Timely investment is essential**
    - Timely investments were made for increased demands and tracked economic growth
  - **Expense sharing**
    - via recovery mechanisms, is a key element
  - **Starter funds from foreign aid**
    - later replaced by growth-led indigenous funding formed a useful model
  - **Efficient operational management is essential**
    - Regulation of discharges and water quality is an essential parallel activity

Brazil

- **Key Issues Addressed**
  - Pollution from untreated sewage discharges
  - Toxic materials
  - Water quality monitoring deficit
- **The Policy Response (Capacity building)**
  - National Water Agency created a National Water Quality Evaluation Program
  - States Agencies implementation of
  - monitoring networks in accordance
  - National Water Quality Monitoring Network
- **Lessons**
  - **Growing public consciousness to water quality**
    - Law on access to Environmental Information 2003
    - Requires state level annual reporting
  - **National Water Quality Evaluation Program**
    - National water Agency 2000
    - National water quality report 2005
  - **Nine states with no monitoring networks**
    - Logistical hurdles in the Amazon basin
  - **National guidance, coordination and reporting**
    - National Field Guide to Water, Sediment, and Biological Sampling. Released in 2011
    - Surface Freshwater Quality in Brazil – Outlook 2012
    - Water Quality Portal 2010
    - Capacity building –Water Knowledge for Management
    - Memorandum of Understanding with all 26 States to implement the national network
  - **State to Federal data flow still slow**
  - **The future National Sanitation Plan with further drive improvements**

Spain Duero Basin Authority

- **Key Issues Addressed**
  - Sustainable Wastewater Treatment for Small Villages
  - Capacity building in Councils
    - Information and training
    - Citizen awareness
- **Activities and Tools**
  - Project and execution of 13 pilot wastewater treatment plants.
  - Project "Mayors Schools" (workshop and field visits to learn in the field)
  - Book "Guide to sustainable wastewater management in small villages"
- **Outcomes**
  - Development of mutual trust (local and basin authorities)
  - Knowledge awareness about wastewater treatment.
  - Local councils are more prone to invest in wastewater treatment plants
  - More reliable information about operational costs in sustainable plants.
  - Replication potential
- Lessons
  - **What has worked well?**
    - Commitment and involvement from Duero Basin Agency managers and technicians.
    - Support from other organizations (NGOs and provincial administration).
    - Good outcomes from the pilot plants.
  - **What can be improved?**
    - Training in public participation would be useful for Duero Basin Agency technicians
    - Communication should be improved to get more people attending the workshops and field visits.

WIPO GREEN

- **What is WIPO GREEN**
  - an interactive marketplace that connects technology and service providers with those seeking innovative solutions
- **Scale (after 1 year of operation)**
  - 400 technologies and 10 water sector technology needs
  - 54 partner organisations in 5 continents
  - 300 users
- **Aims**
  - WIPO GREEN seeks to facilitate technology transfer by connecting different actors in the technology commercialization chain
- **Issues addressed**
  - WASH
    - Eco-friendly sanitation
  - RWM
    - Solar energy pumping
    - On-line management
  - Water quality
    - Treatment lagoons
    - Sustainable cleanup systems
  - Disaster risk management
    - Micro-sensors for wireless flood detection
    - Integrated rain and flood water utilization technology
    - Water-deficient aquifer exploitation
- **Current Activity**
  - Piloting a project on waste water treatment in Indonesia, Vietnam and Philippines.
    - Identify technology needs
    - Identify providers
    - Uploaded to database
    - Matching workshop event
      - with technology seekers/owners/stakeholders/finance/regulation