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ORIGINAL PAPER

Factors in reliable treatment plant operation for the production of safe water

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Abstract This contribution to the International Congress on Production of Safe Water, Izmir, Turkey, 20–24 January, 2009, relates to general aspects of a water supply undertaking rather than to particular technologies or chemistries for water treatment. The paper offers a ''creative problem solving'' approach following Fogler and LeBlanc (Strategies for creative problem solving. Prentice Hall, NJ, 1995) as a model for generating sustainable solutions when water quality and safety problems arise. Such a structured approach presents a systematic methodology that can promote communication and goal-sharing across the inter-related, but often isolated and dispersed, functions of water scientists and researchers, engineers, operations managers, government departments and communities. A problem-solving strategy, or ''heuristic'', invokes five main steps (define; generate; decide; implement; evaluate). Associated with each step are various creative and enabling techniques, many of which are quite familiar to us in one form or another, but which we can use more effectively in combination and through our increased awareness and practice. For example, taking a fresh view of a problem can be promoted by a variety of ''lateral thinking'' tools. First-hand investigation of a problem can trigger new thinking about the <u>real</u> problem and its origins. A good strategy implementation will always address each and every <u>step</u> (though not necessarily every possible <u>technique</u>) and will use them at various stages in the search for and implementation of solutions. The creative nature of our experience with a problem-solving heuristic develops our facility to cope better with complex formal situations, as well as with less formal or everyday problem situations. A few anecdotes are presented that illustrate some of the author's experiences relating to factors involved in safe water supply. Here, the term ''factors'' may signify <u>people</u> and organisations as <u>agents,</u> as well as meaning those <u>aspects of a problem</u> situation that need to be taken into account.

Keywords Problem-solving · Water Systems · Safety · Operation · Arsenic

Introduction

The author's experience in South Africa has not, so far, involved arsenic problems in water supplies. Although a threat of arsenic pollution exists and seems to be associated mainly with old abandoned cattle dips and with mining activities, arsenic in drinking water is not a general problem (evidenced by the few published papers or reports) as in the case

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of Izmir in Turkey and various other countries. However, extension of improved formal water services to rural areas or communities near mining activities may expose some future difficulties. The author's interest in these arsenic problems, therefore, arises more from a vision of the rapid pace of innovation and technological and commercial developments in water treatment materials and ''hybrid'' process combinations and a growing concern about how this technology may be implemented and sustainably managed. It is interesting to study how solutions to local problems evolve: some are relatively new or ''high-tech'' solutions being applied in developing communities. An important evolution of learning occurs—often starting from the perceptions in government and/or non-government groups to the decisions and actions of persons involved on widely differing scales of responsibility in water supply undertakings. It is not always an efficient evolution and older lessons often have to be re-discovered!

Plant reliability in context

The author offers the following perspective of the main aspects to which safe water supply project undertakings should direct attention.

The overall undertaking

- Understanding the community, their cultural values and practices and their environment (geographical, climate, geohydrology, agriculture and economic activities) in context with their health needs.
- Acceptance by administrative or aid groups of a responsibility and initiative to assist.
- Researching the present and future needs and finding sustainable solutions.
- Financing and sustaining management of projects.
- Implementation—construction, operations and maintenance.
- Water safety plans for monitoring, review and reflection (feedback) for sustained effectiveness and development for future needs.

It is common to find each of these being seen as a specialist activity and each agency or factor waiting upon others to indicate the scope and content of their delivery. Appreciation of the importance of interactions and communication is frequently inadequate and problematic. A common strategy for creative interaction might be extremely valuable in overcoming such shortcomings in many situations, and should be supported by shared understandings of the interdependence of sustainability of each component in the venture, e.g. pumps do not continue to function without appropriate supply of future power (of some form!). Where water treatment is involved, the interaction of health, agriculture and waste disposal/pollution management interests (mentioning only the main elements) must be detailed and understood at all stages: from investigations of sources of water, resource planning and protection, engineering design and quality monitoring and assurance.

Aspects of safe water supply

The key aspects that we normally consider include:

- Availability of and access to a sufficient water resource.
- Chemical quality.
- Microbiological quality.
- Aesthetic quality.

We should add to these the need for monitoring and analysis and, most importantly, the need for prompt response, recording and communication of data and follow-up action in case of departures from adopted or applied standards. The selection of appropriate standards is also a matter for interaction between all factors in a water supply undertaking. These are aspects that water safety plans address (Pettersson et al. 2007).

Treatment plant reliability?

In terms of quantity, we think of the integrity of infrastructure and equipment. In regard to quality, we are usually concerned about integrity of the processes selected and the chemical agents involved. These are only parts of a much broader perspective that involves the people and systems that manage the reliability and put in place practices that manage various risks to sustaining them. While design teams and engineering teams work to assure integrity, it is the organisational policy and culture that determines the continued performance of the venture. Creative problem-solving strategies should, therefore, be a prime concern in those sectors, as they represent the major enduring factor in safe water supply. Designs can be changed or replaced, but poor administration is more difficult to re-design or replace.

Managing the safety of a water supply

A safe water supply to the consumer, therefore, depends on the integration of all operational aspects of the entire water supply undertaking. In particular, the following stand out:

- Understanding of the concept of RISK and how to define it and find mitigations to control the impact of situations that could arise.
- Applying thinking models that encourage “SOURCE TO TAP” investigation and monitoring throughout all departments (internal and external agencies).
- Life cycle study of the materials and processes involved.
- Development of water safety plans and related tools that will assist in the management of risks (for example, the EU TECHNEAU initiatives (Pettersson et al. 2007).

In order to accomplish the above, we can consider the following needs:

- Information:
    - Survey and audit of the entire undertaking.
    - Water quality monitoring/analytical practices.
    - History of wells and other resources.
    - Geo-hydrology.
- Training for all involved (including outsourced contractors) in maintenance and operations.
- Resource protection: depends on and involves all departments cooperating and sharing goals and principles:
    - Health.
    - Education.
    - Agriculture.
    - Mining.
    - Energy.
    - Non-governmental organisations and their influence on water demand management and public attitudes towards pollution, littering, conservation, recycling, reuse etc.

The five “building blocks”

The basic outline of the approach to a strategy for creative problem-solving is represented by the following five steps: define; generate; decide; implement; evaluate.

“*Define*” is regarded as the base building block upon which all the others rest. The key advice is to “solve the REAL problem—NOT the *perceived* problem”.

Therefore, the first step is to define and *explore* the problem/s and origins. Thus, one may more carefully identify the *real* problems, rather than merely repeat existing statements and *perceptions* about problems and, thereby, avoid expensive projects based upon ineffective or inappropriate solutions. To explore a problem successfully requires study of its background—taking into account as much information as can be acquired from all available perspectives and sources.

Taking a fresh view of a problem is promoted by a variety of “lateral” thinking tools and techniques and allows a range of possible solutions to be generated. For this second step, it is necessary to develop a few alternatives and, in order to decide which is optimal for implementation, to analyse potential problems that might result from implementation of the alternative potential solutions.

New or potential problems that might be created by proposed solutions may include: introducing technological or managerial complexity; introducing new, unreliable or unfamiliar operating procedures; omitting the re-orientation or re-training of role-players; failing to integrate all components in the contexts of local, regional or larger systems; failure of a proposed solution due to inadequacy or non-existence of supporting infrastructure.

The decision (third) step also responds to various tools and techniques and leads onto the implementation (project management) step. Finally, the effectiveness of solutions needs to be evaluated in regard to the probability of overall success (including costs involved) and relevant ethical and safety considerations. Once a solution is implemented, monitoring and evaluation is still needed in order to ensure successful management of the situation within the overall organisational context of the water supply operations.

Some creative problem-solving techniques

This paper should not attempt to present a short course—rather, the reader is referred to various excellent resources:

- Fogler and LeBlanc: "Strategies for Creative Problem Solving" (comprehensive and easy to use).
- Twiss, B: "Managing Technological Innovation", (Ch. 3—"Creativity and Problem Solving") 3rd Ed. 1986/7 (Pitman).
- "Lateral Thinking" and other books by Edward de Bono.
- Laura Novick: http://www.vanderbilt.edu/peabody/novick/.
- Google: "Duncker diagram".
- Also, explore these materials: http://www.engin.umich.edu/dept/che/research/fogler/publications.html

Some of the key advice explained in these resources includes (quoting freely):

- ''Start with a good base—define the problem well and it will be partly solved!''
- ''Aim to solve the REAL problem not the *perceived* problem!''
- View the problem from different perspectives:
  - Other points of view
- Explore the boundaries of the problem:
  - Where, when, what, etc.
  - Where NOT.
- Search for the NEEDS:
  - temporarily ignore the ''solutions''.

Most of the time, we do all of these steps in our work, but how do we apply this excellent advice? Firstly, we could be more conscious of our strategy (or lack of one?). Secondly, we should cultivate our creativity so as to enhance our ability to innovate.

Why ''creative''?

"Creativity is the ability to improvise and adapt to change. It is the ability to look beyond the obvious, to see new uses for things, new ways of doing things, connections between things that on the surface seem unrelated".

(as quoted by Fogler: Nancy Ross-Flanigan: Detroit Free Press, March 28, 1995).

Author's anecdotes

The case of the jam tin

Bad microbiological results were found at a small town of about 500 people. Its small cohesive character and the predominance of a farming culture and approach to the necessities of life encouraged a pro-active attitude to any unsatisfactory situations. However, microbiological water quality, being intangible for the ordinary citizen until some discomfort occurs, is not one of those. Chlorine-related tastes and odours are, on the other hand, very noticeable and disliked generally. The town originally received its chemically and microbiologically excellent quality water from very safe and adequately protected borehole resources which delivered water into a concrete reservoir provided with a tin roof. The openings around the edges of the roof were protected by wire mesh ventilators against birds but had become dilapidated. The responsibility for pumping water and general maintenance of the water system was contracted to the local motor repairman. He had been provided with a supply of sodium hypochlorite solution with instructions to add to the reservoir in prescribed measures each time he pumped between specified levels. That was in the previous year! On a visit to investigate the causes of the continued bad results found by the laboratory 600 km away (samples were taken on monthly field trips), the author asked the following questions and received the following answers:

Q How often do you pump?
A Almost every day.
Q How much chlorine solution do you add every time you pump?
A One small jam tin (note: this is about 250 ml).
Q How long does the 25-l supply of hypochlorite solution last?
A More than a year because I only add it once a week!
Q Why do you not add the chlorine solution every time you pump?
A The people in this town don't like ''chlorine'' in their water! I have to lock my doors at night if I add any at all—otherwise they would do me harm!

The REAL problem? Could "chlorination" have been an inappropriate strategy to overcome the potential of contamination of the reservoir by birds nesting in it or to avoid the cost of some substantial repairs and upgrading of the vents?

The case of the failing de-alkaliser plant

An aquifer under dunes near the sea provided a relatively hard, but otherwise high-quality water supply to an industrial centre with a residential component of about 2,000 homes. An ion exchange de-alkalisation plant had been installed consisting of three 7,000-l resin beds, a carbon dioxide stripping tower and a pH correction section. Service cycles had declined and resin loss was noted on opening the vessels.

As a supplier of technology and consultant, the author was contacted to advise on the correct resin to specify in the tender documents for procuring resin supplies. The proposed problem statement that gave rise to the requested public tender service was to "supply and install new resin to restore reduced service cycles on the de-alkaliser plant''.

On further investigation, and because the entire installation and water supply scheme was viewed as one unit by the author, it was found that, due to the failure of borehole screens, boreholes had been pumping sand into the main reservoir feeding the plant. This reservoir accumulated the sand and a check had been made to ensure that it did not ever reach the inlet to the ion exchanger vessels. What was overlooked was that, as the sand level in the reservoir rose over some weeks, flow patterns had changed, resulting in significant carry-over—after everyone had stopped looking out for it!

Sand entering the wedge-wire backwash screens from the ''vee'' side became stuck and was not dislodged during backwash cycles, resulting in breakage of the screens and sand entering the beds, accumulating and displacing resin upwards, as well as disturbing the flow distribution in the beds. All of these conditions contributed to resin loss from the vessels during backwash.

The REAL problem was? Replacing the resin would not have solved the problem, even if the screens were replaced, unless the sand was eliminated from the reservoir. New borehole screens had been installed by another contractor some months earlier. There was an assumption that this had cured the sand problem! The author felt that the situation had arisen because the borehole field management systems were not being integrated with the water treatment plant management and maintenance systems. This resulted in isolated approaches to inter-related problems.

A risk assessment training exercise

At a series of training workshops, the author was able to study TECHNEAU materials (Pettersson et al. 2007) and participate in a field trip to a water treatment plant supplying about 10% of the consumption of a large modern city. What can go wrong at a water treatment plant that might affect the safety of the water supply? These were our initial concerns:

- The treatment process (design and capacity)?
- Failure of coagulation, flotation, filtration, carbon adsorption, chlorination processes?
- The operating environment (skills and monitoring)?
- Machinery and equipment maintenance failures?

A risk assessment training workshop, however, had taught us to consider, in a "source to tap" approach, to always:

Consider FIRST:

- the catchment area
- activities therein
- impoundment dam
- monitoring and
- analytical support

Consider SECOND:
the treatment plant and process problems (as we initially perceived the likely concerns and problems).

Our prior perceptions were that we would look at a conventional water treatment process treating about 40 Ml/day of surface water from an impoundment that was part of a nature reserve. This seemed an ideal safe water resource.

Actually, we learned that its catchment received treated wastewater—40 Ml/day from a wastewater treatment plant 20 km away—so that it effectively became a water recycling plant partly supplemented by rainfall in the catchment. We learned also that algal blooms in the impoundment were a frequent occurrence, and that tastes and odours had been anticipated at the design stage and carbon treatment had been included in the process system. The main plant operating problems reported by the plant operators included electrical power failures, shortage of treatment chemicals, difficult washing and carbon renewal in the gravity carbon filters. The REAL problems being experienced at that plant might be related more to the overall situation in the catchment. A general problem statement might be that we do not YET totally integrate our resource management efforts! Will the information age change that?

Generating solutions

In closure, as an example of one of the techniques recommended in our problem-solving resources, let us use a ‘‘Duncker diagram’’ technique (Fogler and LeBlanc 1995) to find some new ideas about the arsenic problem in water supplies and aquifers in the Izmir area. We start with the original problem statement as it was introduced to us the first time (Table 1).

The last suggestion, even though it is amusing and not practical, brought out a new problem statement: “Reduce exposure to arsenic in the environment”. Table 2 creates a different perspective.

This brings us to a quite different approach to the problem. New problem statement: “Optimise technology uses and applications”. We now have a different viewpoint with a wider range of options to consider and evaluate. This allows us to proceed with the selection stage, requiring feasibility studies and, possibly, further research and development before reaching an implementation. Even if new technology is not adopted and applied, the strategic systematic approach to the study of the problem gives us more certainty that all possibilities have been thoroughly researched and considered.

Table 1 Our first study of the problem and the possible solutions we generated

Original problem statement	‘‘Remove arsenic from drinking water’’
Desired state	Make it OK NOT to achieve desired state
Less As in water from wells	NOT less As in water from wells
General solution	
Treat the water from wells	Treat water NOT from wells
Specific solutions	
Adsorption	Develop recycling technology
Ion exchange	Blend with other sources
Membranes	Bottled water
	Ban water drinking
	Supply free beer! (suggested by students)

Table 2 Our second review of the problem—giving fresh insights

New problem statement	‘‘Reduce exposure to arsenic in the environment’’
Desired state	Make it OK NOT to achieve desired state
Less As in water from wells	NOT less As in water from wells
General solution	
Supply LOW As water	Make low TDS water by reverse osmosis!
Specific solutions	
Treat reject from RO plant	Desalinate high As well water
Search for low TDS water	Use intensive AS removal processes on brines
Blend with treated/ other water	Recover As reduced brine rejects

Conclusions

A structured approach to creative problem exploration has been illustrated that helps the development of alternative solutions for both simple and more complex problem scenarios. The need for strategy and training in problem-solving skills has been pointed out through examples quoted and the importance of tapping the creativity and lateral thinking capacity of a range of insights and personal experiences has been emphasised. The reader is, therefore, encouraged to delve into the references (and other similar materials) and engage in a very rewarding skill-building activity that is certain to enhance the success of our combined efforts to improve safety in our resource management and in our provision of vital services.

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