Performance Based Training:
A Proven Approach to Improve Water Treatment Plant Performance

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ABSTRACT

A training protocol based on pursuing optimization activities at water and wastewater plants over multiple years has been developed to allow operators and managers at small and medium-sized utilities to achieve the full capability and performance potential of their existing facilities. The protocol has been piloted in three different states and at 21 utilities. Documented performance improvement was achieved, with 18 of the 21 utilities gaining compliance with the Long Term 1 Interim Enhanced Surface Water Treatment Rule. Operational skills were enhanced to allow the facilities to continue to pursue optimized performance goals of <0.10 NTU. The protocol has demonstrated the potential to impact the way training is done for water utilities in the future.

BACKGROUND

Performance based training (PBT) is the result of years of training activities directed toward improving the performance of existing water and wastewater utilities to meet increasingly stringent regulatory requirements. A brief history of these activities is provided to establish a basis for some of the key components that have been included in the PBT approach.

In the early1970s, the U.S. Environmental Protection Agency (EPA) became concerned about the performance of wastewater treatment facilities. Significant federal funding programs had allowed many utilities, both large and small, to construct new treatment plants. Despite these capital improvements, many plants were not meeting their National Pollution Discharge Elimination System (NPDES) permit requirements. EPA funded a project to evaluate the reasons for the non-compliance of these facilities. Over 100 facilities were evaluated in multiple states. The study results were multi-faceted. First, it was determined that plant limitations were not restricted to simply operation and maintenance practices but also included design and administrative limitations. Second, a protocol called the Composite Correction Program (CCP) was developed that made the evaluations and correction of facility limitations systematic (1,2).

Regulatory requirements also began affecting water treatment plants after the Surface Water Treatment Rule was promulgated (3). At this time, regulatory agencies were concerned with the ability of water treatment plants to meet the new regulations. In response to this concern, and having been extensively involved in the development of the CCP protocol for wastewater facilities, the state of Montana initiated a project with Process Applications, Inc. to adapt the CCP protocol to water treatment facilities (4). In 1988, EPA recognized the potential of the CCP protocol for the water industry and initiated funding efforts to further develop the CCP protocol for water treatment plants. These efforts resulted in two publications that described the protocol in detail (5,6).

The CCP protocol consists of two components—Comprehensive Performance Evaluation (CPE) and Comprehensive Technical Assistance (CTA). A CPE is a thorough evaluation of an existing treatment plant, resulting in a comprehensive assessment of the unit process capabilities and the impact of the operation, maintenance, and administrative practices on the performance of the plant. A CTA is used to improve performance of an existing plant by systematically addressing the performance limiting factors identified during the CPE. The CCP protocol provides a useful tool to evaluate the ability of water and wastewater facilities to meet regulatory requirements and then to facilitate the achievement of cost-effective compliance. In more recent years, the CCP protocol has been focused on achieving optimized performance at surface water treatment plants. For the water industry, this focus on optimization became paramount after a large waterborne disease outbreak caused by *Cryptosporidium* occurred in Milwaukee in 1993 (7).

As the follow-up component of the CCP protocol, the CTA was developed to provide a method for addressing the plant-specific deficiencies identified during the CPE. The cost effectiveness of using the CTA approach to improve the performance of existing water and wastewater utilities has been documented (9,10,11,12). Demonstrated improved performance is the primary objective of an effective CTA, and the ability to "draw the graph" is considered a key measure of success of the CTA efforts. A typical performance improvement graph from a CTA is shown in Figure 1.

Although the effectiveness of the CTA protocol has been demonstrated, the "one-on-one" facilitation approach used during a CTA is resource intensive. With the growing demand to improve the performance of multiple facilities, especially in the drinking water industry, an alternative approach was needed. The successes of the CTA protocol provided valuable insights that were utilized during the development of PBT. These insights are described further. A key finding from the development and implementation period for the CCP protocol for both water and wastewater treatment facilities is shown in Table 1.

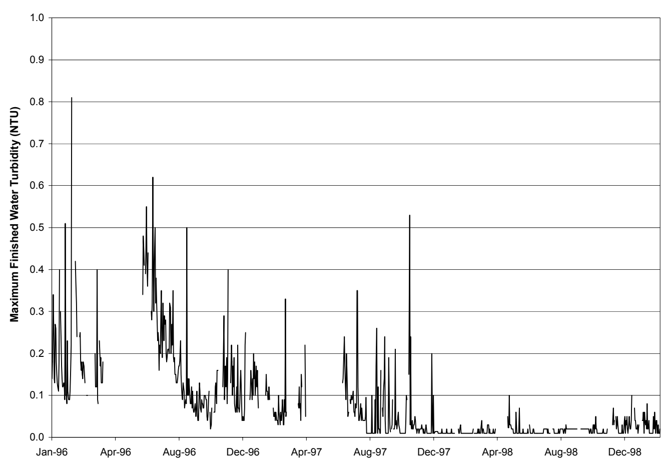

FIGURE 1: Performance Improvement Using the CTA Protocol (10)

TABLE 1: CPE Evaluation Results

Type of Facility	Evaluation Period	Number of Plants	Location	Top Ranking Factor Limiting Optimization
Wastewater	1973 to Present	>300	30 States and 2 Provinces	Application of concepts and testing to process control
Water	1988 to Present	>100	20 States and 2 Provinces	Application of concepts and testing to process control

These results indicate that it is a challenge to apply operational concepts obtained from classroom training or other resources to the day-to-day operation of the individual facilities. This gap in the ability to apply knowledge has been referred to as the "knowing-doing gap" (8). There are several reasons for these results, such as:

- Willingness of organizations and individuals to let talk substitute for action.
- Lack of confidence in implementing changes that could adversely affect public health or the environment.
- Lack of time to implement new ideas.
- Utility philosophy of "we have always done it that way, why should we change?"
- Lack of enthusiasm for change from the "more experienced" operators.
- Higher priority on cost savings than on performance improvements.

Another finding from the CCP protocol development was that the performance limiting factors identified during CPEs included design and administrative issues in addition to operation and maintenance issues. The relationship between these different categories of factors is graphically demonstrated in Figure 2. Typically, process control is defined as data collection, monitoring, and process adjustment activities that allow the operator to achieve optimized performance goals. However, if an operator does not have a capable plant, typical process control will not allow optimized goals to be achieved. The major implication of the relationship shown in Figure 1 is that the definition of process control must be expanded to include "any activity to develop a capable plant and take it to the desired level of performance." Given this definition, the operators' role is expanded to include addressing administrative and design limitations as well as the typical operation and maintenance activities.

As the result of CTA experience, it became apparent that operations personnel had to learn communication, documentation, priority setting, and problem solving skills to address the expanded definition of process control. It was also observed during CPEs conducted at optimized facilities that the associated personnel had developed these skills in addition to the normal technical skills associated with their profession. The conclusion from these experiences indicated that attributes related to leadership and management skills make more of a difference in improving plant performance that those related purely to technical skills. In recent years, during training events, a workshop has been used to list the characteristics and attributes of professional water and wastewater operators at optimized plants. Typical results from a workshop are summarized in Figure 3. The results of these workshops indicate that a majority of the characteristics and attributes that are identified are related to leadership and management. However, most training for operators does not focus on leadership and management skills development.

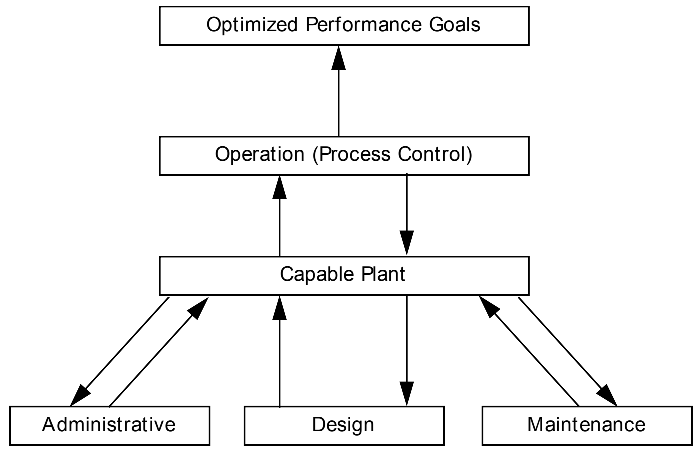

FIGURE 2: Relationship of Factors Impacting Optimized Performance

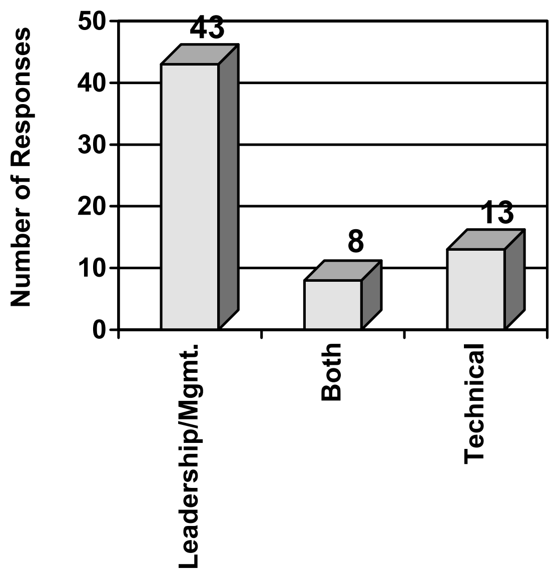

FIGURE 3: Results of Workshop on Characteristics and Attributes of Professional Operators

Another key component of the CTA protocol is the use of a facilitator to work with the utility personnel for an extended time (12 to 18 months) to address the identified performance limiting factors. This timeframe was necessary for the plant personnel to gain confidence; to implement necessary process, administrative, and minor design changes; and to develop responses to seasonal variations. The facilitator was responsible for keeping the focus on optimizing treatment unit processes and operations; supporting development of leadership skills; maintaining staff motivation; and transferring priority setting and problem solving skills to the on-site staff.

Key insights from the development and implementation of the CCP protocol that influenced the development of the PBT protocol are summarized below:

- A key measure of success of the training must be the "ability to draw the graph" (i.e., performance based results).
- The training must impact multiple facilities to maximize use of facilitation resources.
- The knowing-doing gap must be acknowledged and addressed.
- Operators must be capable of addressing administrative and design limitations as well as operation and maintenance challenges.
- Leadership and management skills training is necessary.
- Long-term facilitation is required for transferring priority setting and problem solving skills to on-site personnel.

PERFORMANCE BASED TRAINING

<u>Development</u>

In 1994, the EPA Technical Support Center and Process Applications, Inc. formed a working partnership with the Texas Natural Resource Conservation Commission to improve the performance of surface water treatment plants and thereby reduce the risk of waterborne disease in Texas. Multiple optimization activities based on the CCP protocol were pursued under this partnership, and a core team made up of the partners managed the optimization efforts. The core team decided to pursue the development of PBT for surface water treatment plants through a pilot program. The impetus for developing the new PBT protocol was two-fold. Although a CTA had been successfully demonstrated at one treatment plant in Texas (12), the resources to implement multiple CTAs at facilities throughout the state did not exist. In addition, existing training programs were not demonstrating the capability to draw the performance improvement graphs associated with a successful CTA. The pilot activities were initiated in April 1999. Results from this pilot effort were published in a project report in 2001 (13). Based on the initial positive results achieved in Texas, two other PBT pilot projects were conducted in other states (14, 15).

The protocol described in this paper represents the status of PBT development and includes the enhancements derived from the pilot projects. Unique elements of PBT are summarized below:

- The training is conducted over a 12 to 15-month period.
- A combination of classroom and periodic phone facilitation is used throughout the training period.
- The training is focused on achieving implementation of the training concepts at the participant's utility (e.g., site-specific implementation).
- Leadership and management skills training is integrated with the technical training.

- Priority setting and problem solving skills are transferred to participants to sustain performance improvements.

- Facilitators are trained to encourage development of priority setting and problem solving skills.

- Facilitator and utility participant training is done simultaneously.

- Trainers, facilitators, and participants (including administrators) are held accountable by long term tracking of performance.

Although the training protocol has been demonstrated and enhanced several times through pilot projects, continued modifications to the training approach and materials are anticipated and considered part of the process to adjust for the training participants' progress and understanding.

PBT Components

PBT is considered a process and not an event, and it is comprised of several components. The significant components include: 1) participant/utility selection, 2) facilitator training, 3) formal training sessions followed by facilitation, and 4) follow-up data monitoring. Each of these components is discussed further.

Participant/Utility Selection

The utilities involved in PBT are required to make several commitments and meet certain requirements in order to participate. Key commitments include:

- The same participants should attend all formal training sessions. Since the training is progressive, it is important that the same participants attend each session. Sending two participants from each facility is highly recommended.

- Utility administrator(s) should attend the first and last formal training sessions. Administrator attendance is required to enhance administrative support for the project. At the first session, they are informed of the project goals and expectations, and at the last session they witness the documented progress that their utility has achieved.

- Participants must complete the homework assignments associated with the training. Each session is accompanied by a homework assignment designed to allow participants to implement the session activities at their own plants. Facilitator support is provided between sessions to support and encourage progress.

- Participants must have access to a computer with spreadsheet capability. The responsibility for performance monitoring with a standardized computer spreadsheet is given to the participants. Several of the small facilities that have participated in the training have utilized a city clerk with computer skills to assist in data handling.

- Utilities must have or be in the process of installing on-line turbidimeters for each filter. When PBT was initiated, this was an issue. However, recent regulations have made this a requirement for almost all plants.

- Utilities must have jar testing equipment. Most plants have jar testing equipment, although the equipment at some of the smaller facilities may need to be updated.

Other criteria used during the selection process include:

- No major design limitations. PBT focuses on trying to optimize existing infrastructure. If known major design limitations exist such as an undersized plant, the utilities are encouraged to complete the modifications before involvement in PBT.

- No major improvements underway or anticipated during the training period. Plants that are in the midst of construction projects often do not have the flexibility to optimize individual process performance. In addition, operator time is frequently distracted by construction activities.

- Limiting the total number of utilities participating in each training series to about eight. Because of the hands-on nature of the session workshops that are conducted at the plant sites, there are practical limitations to the number of utilities that can be accommodated.

For the pilot projects that were completed, most of the selected plants were not in compliance with the requirements of the Interim Enhanced Surface Water Treatment Rule (IESWTR) or the Long Term 1 Enhanced Surface Water Treatment Rule (LT1 ESWTR) (16,17).

Facilitator Training

In addition to trainers who conducted the one-day sessions, an important component of the training program was the use of facilitators who were assigned one or several water systems to work with during the training period. Facilitators play a key role in the success of the PBT approach. Facilitators for the PBT pilot projects were either state or federal regulatory personnel or employed by federal agencies associated with the facilities (e.g., Indian Health Service). Some of these personnel did not have extensive experience in the operation of water treatment facilities. Others had extensive experience, not only in operation but also in providing training for water treatment plant operators.

Because of this varying experience level and the "new way of doing business" that PBT presents to experienced trainers, facilitator training is provided in conjunction with the training for the utility participants. A summary of significant facilitator activities includes:

- Participate in a one-day training event prior to PBT Session 1. This training event introduces the facilitators to the PBT protocol and covers the facilitator's roles and responsibilities. Tools that are used throughout the PBT sessions are introduced and provided to the facilitators (e.g. an optimization assessment spreadsheet used to document plant performance and a jar test spreadsheet used for jar test calibration and data collection).

- Participate in the five PBT sessions. In many cases, the facilitators learn skills along with the participants. By attending and observing the sessions, they become aware of the expectations on the utility participants.

- Complete facilitator homework assignments. The facilitators receive assignments at each session just like the participants. The assignments typically focus on activities to ensure that the participants complete their homework.

- Maintain utility contact between training sessions. This is one of the challenges for the facilitators to implement and often is highly plant-specific. Typically, a facilitator is assigned one plant, although some facilitators have worked with as many as four plants at one time. The frequency of contact with individual plants has ranged from weekly to monthly and depends on the response from the utility. The focus of the calls is to encourage the plant staff to complete their homework assignments. Plant personnel will often try to get the facilitator to "give the answers" and solicit support in "troubleshooting" at their plant. In these situations, a facilitator must remember that they are trying to teach priority setting and problem solving skills, and they must resist the temptation to give answers. This approach is often easier for the facilitators with less experience in water treatment. The facilitator documents phone calls so that a record of activities and responses is maintained.

- Review and comment on all plant documentation. Another key facilitator responsibility is to provide feedback to the plant staff. This important activity shows the staff that their efforts are being monitored and that submittals are expected. Comments are typically provided on the data, operational guidelines, and special studies requested in the participants' homework.

- Participate in routine conference calls with other facilitators and PBT trainers between training sessions. Conference calls are typically conducted between the training sessions to provide the facilitators with an opportunity to discuss their participants' progress and technical challenges that they are experiencing.

- Expand utility involvement to other staff and to the administration if support is not being provided. This activity depends on the utility. In some cases, experienced participants who are reluctant to involve other plant staff in project activities must be encouraged to pursue such involvement. The involvement of plant administrators is usually necessary when minor design modifications, changes in chemicals, or staffing adjustments are required to meet the PBT objectives.

- Teach priority setting and problem solving skills. This is the most critical responsibility of a facilitator. If these skills are not transferred to the utility staff, achieving and sustaining improved performance cannot be accomplished.

During the development and implementation of the facilitator activities described above, several significant challenges were documented. One of the most common challenges was maintaining consistent follow-up with the utilities. The facilitator must recognize that a commitment to assuring regular contact with a participant is an integral part of the facilitator's role and that this commitment is crucial to the success of the project. Another challenge was related to gaining skills in redirecting troubleshooting requests back to the participants. The facilitators were taught to encourage the participants to identify and conduct site-specific special studies that allowed them to obtain their own answers. Gaining this attribute is often difficult for experienced trainers and water treatment personnel. Some facilitators were challenged by the recognition that improved performance and skills transfer is the endpoint of PBT, not facilitator recognition.

Formal Training Sessions

Currently, the PBT series is focused on optimizing particle removal from surface water treatment plants. Five sessions conducted over a 12 to 15-month period are used to address this objective. The sessions are progressive in nature, with each session building upon the previous session. In some instances where participants have had to miss a session, the facilitator has conducted a makeup session with the participants to ensure that they remain current in the training process. The session topics have been derived from the extensive plant optimization experience that was obtained during development of the CCP process over a period of several years. The topics address the highest-ranking performance limiting factors observed over the years. By concentrating the training on the technical knowledge that has been distilled down to those topics necessary to impact a plant's performance (e.g., strategic knowledge base), the PBT facilitators and participants can aggressively gain competency on each topic, and these focused efforts can be applied to achieve more immediate results at the participants' facilities. The identification and use of a strategic knowledge base is the foundation for expanding the current PBT series into other optimization areas such as disinfection and disinfection byproduct control.

The training approach used to address the knowing-doing gap is founded on the principle of "hear it, see it, and do it." The participants hear presentations on the strategic aspects of an identified topic; they see and participant in workshops on the topic; and, back at their plants, they do homework assignments related to the topics. This process also provides opportunities to introduce key leadership and management skills training. The workshops and verbal reporting teach communication skills and encourage the participants to organize their thoughts. Documentation of operational guidelines and special studies teaches writing and communication skills as well as skills in obtaining data to justify decision-making. Implementation plans, used to outline homework assignments, teach time management and skills in breaking down complex activities into doable tasks. The presentations that the participants make during the training sessions result in a higher level of confidence because they are talking about their day-to-day job. Peer pressure is utilized in a positive way throughout the PBT process. Peers will often challenge participants that do not complete assignments before they are challenged by the instructors or facilitators.

The structure and content of each of each of the one-day training sessions is described further.

PBT Session 1 – Adoption of Goals and Development of Data

- The main purpose of Session 1 is to encourage the participants to adopt optimized performance goals and to initiate data collection to support assessment of their progress on meeting the goals. Table 2 summarizes the goals that the participants are asked to pursue. Some participants are reluctant to adopt these aggressive goals, especially when they are often not meeting the IESWTR or LT1 ESWTR requirements.

- Utility administrators are requested to attend the first session. This allows them to become aware of the goals of the project and the expectations of the participants.

- A computer spreadsheet that summarizes plant data on an annual basis is introduced and handed out to the participants. This spreadsheet, called Optimization Assessment Software (OAS), is a powerful tool that allows operators and facilitators to track progress toward optimization goals. It has become the foundation for assessing the impact of PBT. The turbidity data is gathered for a period of 12 months before, during, and for 6 to 12 months after the formal training activities for evaluation. In all cases, the software utilizes maximum turbidity values for the day and, as such, is typically a more critical assessment than what is required by the regulatory process.

TABLE 2. Summary of Microbial Optimization Performance Goals

Minimum Data Monitoring Requirements

- Daily raw water turbidity.
- Settled water turbidity at four-hour time increments from each sedimentation basin.
- On-line (continuous) turbidity from each filter.
- One filter backwash profile each month from each filter.

Individual Sedimentation Basin Performance Criteria

- Settled water turbidity ≤ 1 NTU 95 percent of the time when average source water turbidity is ≤ 10 NTU.
- Settled water turbidity ≤ 2 NTU 95 percent of time when average source water turbidity is > 10 NTU.

Individual Filter Performance Criteria

- Filtered water turbidity ≤ 0.10 NTU 95 percent of the time (excluding 15-minute period following back-washes) based on the maximum values recorded during four-hour time increments.
- Initiate filter backwash immediately after turbidity breakthrough has been observed and before effluent turbidity exceeds 0.10 NTU.
- Maximum filtered water turbidity following backwash of 0.30 NTU.
- Post backwash turbidity without filter-to-waste capability:
  - Maximum turbidity ≤ 0.30 NTU.
  - Recovery to ≤ 0.10 NTU within 15 minutes.
- Post backwash turbidity with filter-to-waste capability:
  - Return to service at ≤ 0.10 NTU.
- Maximum filtered water measurement of less than 20 particles (in the > 2 micron range) per milliliter (if particle counters are available).

Disinfection Performance Criteria

- Provide CT values to achieve adequate log inactivation of *Giardia* and viruses.

- The OAS generates a turbidity profile of raw, settled, and individual filtered and combined water turbidity as well as area graphs of the settled and combined filter turbidity showing the percent of time performance targets were achieved for each water treatment plant. Examples of these graphs are shown in Figures 4 and 5.

- The turbidity profile line graph shown in Figure 4 represents a combined plot of the raw water turbidity, the daily maximum settled water turbidity, the daily maximum individual filtered water turbidity, and the maximum combined filtered water turbidity. These data sets are plotted using a semi-log scale to allow a wide range of data to be shown on one graph. This is the most popular graph for the participants to use during PBT because it provides a visual picture of overall plant performance and it shows progress on meeting the optimized performance goals.

- The area graph of combined filter turbidity in Figure 5 shows the percent of the time that the maximum daily combined turbidity achieves 0.30 NTU, 0.20 NTU, and 0.10 NTU goals. This graph allows the PBT participants to observe their progress toward the optimization goal while also observing progress toward other less stringent goals. The area graph is utilized because achieving optimized performance goals is a long-term effort (i.e., three to five years) and interim progress is motivational for the participants. It has been observed that the achievement of the 0.30 and 0.20 NTU goals is often obtained during the training period, but meeting the 0.10 NTU goal on a consistent basis typically requires additional time. This is demonstrated in Figure 5. After the start of PBT, the plant was able to achieve 0.3 and 0.2 NTU performance consistently; however, achieving the 0.1 goal is more elusive and will require additional optimization efforts by the plant staff.

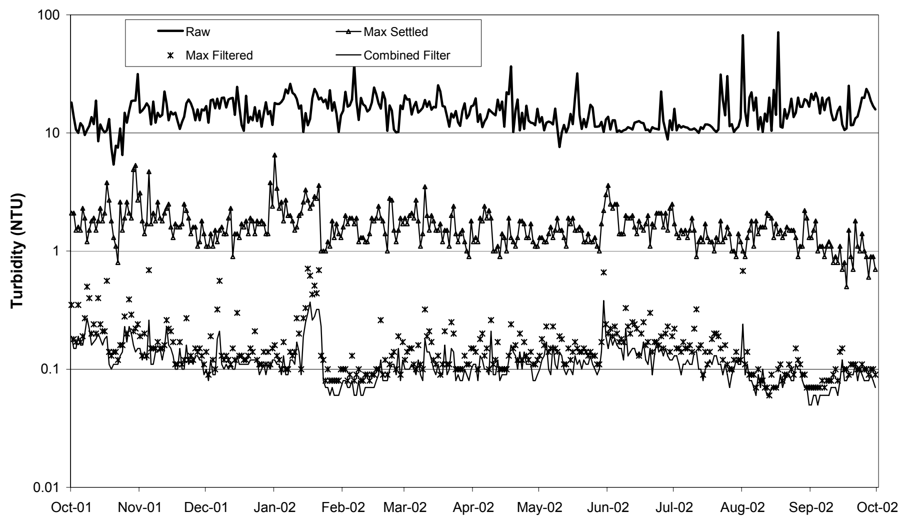

FIGURE 4: Example of Turbidity Profile Graph Developed by the OAS

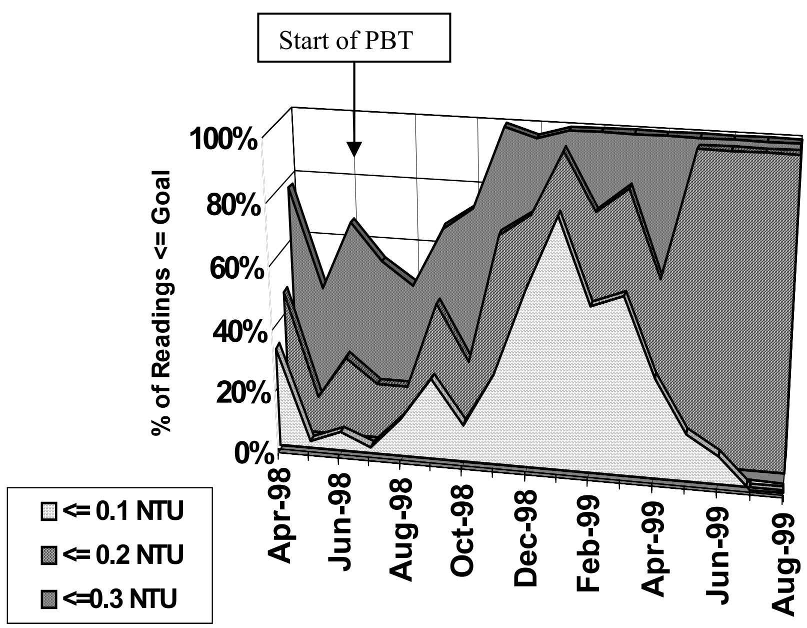

FIGURE 5: Example Area Graph of Combined Filter Turbidity Developed by the OAS

- Session 1 is conducted in a classroom setting, and workshops are used that allow the participants to develop operational guidelines on goal setting and sampling and data development. These workshops provide a template for conducting a similar exercise at the participants' facilities. The first session workshops typically lack interaction since the participants do not know each other or the facilitators or trainers. In addition, the presence of the administrators often impacts open communication. Peer-to-peer communication is encouraged throughout the session.

- Homework focuses on formalizing the adoption of performance goals by each plant/ administration and on the development of site-specific guidelines to support data collection and development.

- A site visit by the facilitators is encouraged following Session 1 to allow them to become familiar with the plant staff and facility that they will be working with and to provide support with setting up computer data entry. The facilitators are also requested to begin gathering data on unit process volumes and equipment to support the jar testing efforts introduced in Session 3.

PBT Session 2 – Developing Priority Setting and Problem Solving Skills

- The main purpose of Session 2 is to begin the process of transferring problem solving skills to the participants. Participants are focused on identifying operational solutions first before directing their efforts to physical facility modifications. A special study format is introduced that applies the scientific approach to evaluating plant conditions (i.e., make the facility research oriented).

- A key activity of the PBT protocol is that the participants are asked to provide handouts and formally present the results of their homework efforts at the beginning of the session. Questions are encouraged during the presentations, and applause is given at the end of each presentation. This activity has been successful in applying peer-to-peer pressure in a non-threatening way.

- Session 2 is taught in a plant setting (i.e., typically a plant participating in the PBT training). Example cause and effect special studies are utilized to ensure that the special study approach is understood. Example special studies include filter bed expansion, measurement of backwash water turbidity during the backwash cycle, measurement of filtered water quality when a filter is put back on-line, and measurement of performance impacts on the operating filters when one filter is backwashed. These studies provide relatively straightforward information to document, interpret, and teach special study skills. At the conclusion of the workshops, the participants are requested to report their findings to the other utility participants. Workshop groups are assigned to ensure that participants are working with personnel from other facilities. Facilitators are typically grouped together during the training session so that they experience the same types of special studies that they will be required to facilitate their plants through during homework efforts. To maximize the operators' learning experience and because of the tendency for the operators to look to the facilitators for the answers, facilitators are not grouped with plant participants.

- Homework focuses on conducting similar special studies at the participants' utilities. Learning the special study skill is more important at this point in the training process than solving specific problems at the facilities.

PBT Session 3 – Coagulation Control Tool Development

- The main purpose of Session 3 is to establish the steps necessary to make jar testing a valuable process control tool for each utility. The special study format introduced in Session 2 is used to establish a jar test calibration approach for individual facilities. Emphasis is placed on completing the jar test calibration before this tool can be used to optimize plant processes (e.g., coagulation).

- Session 3 is taught in a plant setting. Two to three jar test stations are required to complete the workshop for this session. In addition to the calibration special studies, workshops are conducted on stock solution preparation and chemical feed pump calibration.

- At the beginning of Session 3, the participants make verbal reports on the Session 2 homework assignments, including their special study activities.

- Homework for Session 3 focuses on conducting special studies related to jar test calibration at the participants' plants.

PBT Session 4 – Assessing Current Plant Performance/Applying Skills and Tools

- The focus of Session 4 is to review historical plant performance and assist the participants in prioritizing key activities that could help them in achieving or further enhancing plant performance. The OAS graphs for each utility are projected on a screen, and all the participants are asked to critique the performance and identify high priority areas where optimization of plant performance could be pursued. Facilitators are asked to be prepared to stimulate discussions of the performance data, if necessary, but to refrain from dominating the discussions.

- Session 4 is taught in a classroom setting. Questions and communication are encouraged among the participants.

- During Session 4, the participants make verbal reports on the Session 3 homework assignments, including reporting on their jar test calibration results.

PBT Session 5 – Reporting on Success

- The focus of Session 5 is the presentation of plant performance by the utility participants to the managers. In addition, presentation of special study results provides an opportunity for the participants to demonstrate the problem solving and communication skills that have been developed during the training.

- The participants are encouraged to continue to use the skills they have developed to sustain or further enhance performance. The applicability of skills learned to solve other performance challenges such as disinfection by-products or distribution water quality is encouraged.

- Session 5 is conducted in a classroom setting. A workshop on the benefits and/or challenges of PBT is conducted. A workshop is also conducted with the facilitators to establish follow-up data collection assignments and to assess further program enhancements. Typically, a six-month to one year time period is used to gather data after the last session to assess the plant performance and indirectly assess the effectiveness of the skills transfer to the plant staff.

- Formal facilitation is not provided after Session 5.

PBT Impacts

Performance Impacts

The impact of PBT on plant performance for the pilot projects that serve as the foundation of this paper is summarized in Table 3.

TABLE 3: Summary of the Impacts of PBT

Sponsoring Agency – Training Period	No. of Water Systems	Performance Before PBT	Performance During/After PBT
TNRCC (12) 3/99 – 5/00	8	0 < 0.30 NTU	6 < 0.20 NTU end of training 4 < 0.20 NTU one year following training 1 < 0.10 NTU one year following training
EPA Region 8/ Shoshone Utilities (14) 1/01 – 2/02	7	3 < 0.30 NTU	6 < 0.30 NTU for six-month period following training 4 < 0.20 NTU for same period 2 < 0.10 NTU for same period
Louisiana (15) 4/01 – 4/02	6	1 < 0.30 NTU	6 < 0.30 NTU for six-month period following training 3 < 0.10 NTU for same period

Nineteen of the twenty-one facilities that participated in these pilot projects were small systems (< 3,300 population served). Before the training was initiated, only four of the utilities were producing water consistently less than the LT1 ESWTR requirements for finished water of 0.30 NTU. Immediately following the training, 18 facilities were able to consistently meet the LT1 ESWTER requirements. Of these 18 facilities, 16 were able to meet the LT1 ESWTR requirements for six months or greater. Six of the facilities were able to achieve the optimized performance goal of 0.10 NTU following the training. Monitoring post PBT performance of the participants' plants for one year is typically recommended. Only six months of post PBT data was available for the EPA Region 8/Shoshone Utilities because of the project completion schedule. Six months of post PBT performance data was available for the Louisiana facilities at the time of this paper development, but the state continues to monitor the performance of these PBT plants.

These performance improvements are significant in that they were achieved with existing facilities and staff, and most of the utilities were small systems that are often challenged in meeting the new regulations. It is significant that six of the facilities were able to achieve the combined filter turbidity goal of 0.10 NTU with existing facilities. Continued performance improvement is anticipated from most of the facilities due to the skills transferred during PBT.

Another very tangible impact of the training is the problem solving skills that the participants are taught. The special study format allows the participants to systematically solve the myriad of problems that typically inhibit a plant from achieving optimum performance (i.e., they learn to utilize their facility as a place to conduct "research" on identified problems).

A case history special study conducted by one of the participants demonstrates this impact. Facility A is a small utility that is operated intermittently. The plant has three filters, and flow control through the plant had been controlled automatically. As performance improved, the operators realized that they were not able to lower the finished water turbidity below 0.10 NTU. They formed a hypothesis that the fluctuating valves from the automatic control were impacting the individual filter performance. The operators used this hypothesis to initiate a special study on valve control and plant performance. Figure 6 shows the graphical results of the special study. During automatic operation, the filtered water turbidity was above 0.10 NTU. When the operators manually adjusted the valves to control the flow, the performance improved to < 0.10 NTU. Based on the special study results, the operators decided to utilize manual operation. They also planned to compile the results of the special study for the plant administrator to consider modifications for the flow control valves during the next budget period. These results show the dramatic impact of providing problem solving skills to the plant staff.

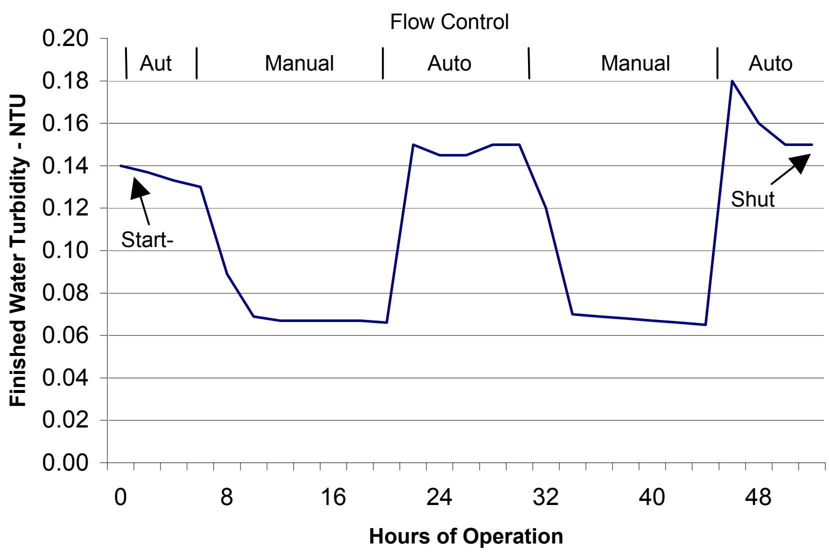

FIGURE 6: Results From Special Study Conducted at Plant A

Intangible Impacts

The intangible impacts of PBT are also significant. These benefits are realized at the operator level as well as the facilitator level. During the PBT period, a transition in the participants was observed in each of the pilot projects. Common observations included increased confidence in public speaking, improved documentation skills, confidence in unit process operation, confidence in priority setting, increased focus on unit process performance, and motivation to continue the optimization process. These leadership and management skills were developed gradually during the training series. The stifled discussion at the first sessions gave way to enthusiastic communications with all of the participants during the later sessions. It is projected that the communication among participants, both informally and formally, during the workshops is a significant component of the training and skills transfer.

The participants established a network of operators, trainers, and facilitators that they feel comfortable in contacting, even following the training sessions. This communication network is a valuable side benefit of the PBT approach.

Another valuable aspect of PBT is that the participants learned skills to document needs through special studies. This data-based approach provides the operators with tools to approach managers with requests for changes to staffing and facilities (i.e., support development of a capable plant; see Figure 1).

Facilitators also acquired valuable training skills by learning to: 1) transfer priority setting and problem solving skills to the participants and 2) avoid trying to troubleshoot problems from a remote location. A majority of the PBT facilitators have indicated that their role as PBT facilitators has greatly enhanced their understanding of the issues facing operators and their ability to lead operators in the formulation of solutions to their own problems.

The following testimonials received from participants and facilitators summarize the intangible benefits of PBT:

- "PBT works! As a tribal member, I have never seen such training where you almost don't want the training to end…you leave very motivated to do a better job and knowing that you are responsible for the work you do." *Shoshone Tribal Member*

- "This training is different from any other training I have attended. There were expectations after every session, and the homework assignments were hard work. I asked my boss to load up the software on his computer so he could see the impact we had on the plant!" *PBT participant*

- "PBT has taught us (operators) to work together as a team. We have become more aware of changes that must be addressed on a daily basis. The program has made our plant performance more consistent, and we are always striving for higher goals than those that are set" *PBT participant*

- "I really saw the operators mature during the PBT series. When I first met John he said, *Give me $20,000 and I can optimize this plant*. Recently, he told me that he really didn't have to make any significant modifications to improve their performance." *PBT facilitator*

- "In my 30 years of service with the government, I have never seen a program that has had as much impact as this PBT series." *PBT facilitator*

- "PBT has been one of the most effective things that the state has done for water treatment plants." *PBT facilitator*

The Future of PBT

PBT offers a variety of opportunities for existing and future training activities. Efforts are underway to add a new training series to address optimization of the disinfection process, including disinfection byproduct control. The same group of facilities could be used to initiate the training on these new technical topics when the strategic knowledge base has been identified and adapted to meet the PBT protocol. Time for the participants to get to know each other would not be an issue, and the training could be implemented more aggressively than during the initial PBT series.

Through a joint effort with EPA Technical Support Center in Cincinnati, Ohio, Area-Wide Optimization Projects (AWOPs) have been implemented in several EPA Regions. These projects provide a facilitated roadmap for EPA Regions and states to follow to formally implement surface water optimization activities in their states (18,19). The AWOP model includes defining follow-up component activities within a state agency that can be used to pursue plant optimization. PBT was introduced into the EPA Region 4 AWOP by presenting the session materials to AWOP representatives and then having them conduct PBT series in their own states. Based on this train-the-trainer approach, four states (South Carolina, Georgia, Alabama, and Kentucky) have implemented additional PBT projects for facilities in their states.

An AWOP is also being conducted in EPA Region 6. In addition to the pilot PBT project in Louisiana, a second PBT series is currently underway with eight water utilities. Arkansas is currently conducting a PBT series with a dual microbial and DBP focus. Texas has completed a second pilot project and is pursuing the option of training a third party to conduct future PBT projects within their state.

Beginning in 2003, AWOPs are being initiated in EPA Regions 3 and 10. PBT projects will be initiated in the states in those regions within the next several years.

CONCLUSIONS

The Composite Correction Program (CCP) provided the experience base for achieving optimized performance from existing surface water treatment plants. Due to recent and proposed regulations and increasing challenges in providing public health protection, the need arose to develop a new training approach that would impact performance at multiple systems. The PBT protocol was developed and demonstrated at twenty-one water utilities; and, in almost every case, improved performance was achieved. The key characteristics that define PBT include:

- Integrating leadership and management skills training with technical training.
- Providing facilitator training and involvement.
- Bridging the knowing-doing gap (i.e., moving beyond talking to action).
- Utilizing a long-term process and not an event (i.e., training series).
- Distilling technical knowledge down to the “strategic knowledge” required to impact day-to-day operation of a plant.
- Transferring priority setting and problem solving skills to utility staff (making a utility a research oriented).

- "Drawing the graph" to demonstrate improved performance at individual facilities.

In addition to the improved water quality that occurred as the result of PBT, many other tangible and intangible benefits were documented. PBT has:

- Demonstrated the capability to improve the performance of small systems to meet the requirement of the LT1 ESWTR.
- Provided operators with leadership and management skills that they can use to pursue optimization at their utilities.
- Provided a documented impact of the success or failure of the training as an integral part of the training package.
- Expanded regulatory personnel's understanding of operational aspects of water treatment plants through their facilitation roles.
- Demonstrated a viable tool for achieving performance improvements at multiple treatment plants.

PBT provides an alternative to conventional training, and it has been demonstrated as a viable approach for achieving improved performance from existing facilities. Individuals and organizations contemplating training for water or wastewater operators should consider this "new way of doing business" in their approach.

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