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ABSTRACT

This paper introduces concepts of sustainability with emphasis on the Natural Step principles. It describes the elements of an Environmental Management System (EMS) and discusses how an EMS can ensure sustainability by using portions of the Kent County (Delaware) Regional Wastewater Treatment Facility's (KCRWTF) Environmental Health and Safety Management Plan as an example. The KCRWTF is the first wastewater facility in the United States to be certified to the ISO 14001, OHSAS 18001, and the National Biosolids Partnership's EMS standards.

WHAT IS SUSTAINABILITY?

An Internet search for the definition of sustainability will provide a wide variety of links. There are over thirty definitions for the word as it is currently used. One of the most common (World Commission on Environment and Development, 1987) defined sustainability as "meeting the needs of the present generation without compromising the ability of future generations to meet their needs". Mihelcic et al (2003) elaborated on this definition by defining sustainability as "a condition in which the use of natural resources and cycles in human and industrial systems does not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment." This definition was recently adopted in the Environmental Engineering Body of Knowledge (AAEE, 2009).

Many organizations look upon sustainability as a union of three distinct

areas: environmental sustainability, economic sustainability, and social or ethical sustainability. This concept has often been referred to as "the triple bottom line" which was first defined by John Elkington (1994) and also referred to as "the three e's: environment, economics and ethics" or the "three p's: people, planet and profit". In the past, many organizations have used the word "or" as in environmental sustainability *or* economic viability, environmental sustainability *or* social (ethical) progress, social progress *or* economic viability. Current sustainability concepts typically replace the "or" with "and".

Being Sustainable

There are many benefits associated with operating a sustainable organization.

Some of these include:

- Reduced energy, wastes, and costs
- Differentiating sustainable organizations from others
- Sidestepping future regulations
- Creating innovative processes and products
- Opening new markets
- Attracting/retaining the best employees
- Reduced improper labeling of products
- Reduced legal risks and insurance costs
- Providing a higher quality of life
- Reduced liability from pollutants
- Being closed out of certain markets
- Reduced attacks on an organization's image
- Improving the organization's public and shareholder image

- Reducing supply problems due to raw materials and energy

There are a number of reasons why sustainability is becoming a strategic issue for many organizations. Some of the major reasons include:

- It's a natural extension of other organizational changes
- Natural resources are becoming a limiting factor
- Environmental issues now involve global consequences
- Health concerns are gaining importance
- Being sustainable produces many unintended benefits
- Energy supplies pose a significant threat
- Associated with these problems are new opportunities

A truly sustainable organization can be compared to a wheel. The spokes of the wheel represent various parts of the organization including its employees, the products it promotes, the revenue it generates, the raw materials it uses, the natural resources it uses and the byproducts it generates. The rim of the wheel represents the various constituencies it affects. These might include: the environment, its customers, suppliers, stockholders, the community in which it operates, and the various competitors and other industries it interacts with. In a sustainable world, all of this is in balance and the wheel rotates properly. If any one of the spokes or rim constituencies is out of balance, the wheel might wobble or collapse.

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Sustainability Principle Models

There are a number of sets of principles that describe the attributes of a truly sustainable organization. The Permaculture Principles developed by Mollison and Holgrem (1978) represent one of the early developments. Several other sets of principles have been developed since 1995. A very recent set of principles is the International Organization for Standardization's (ISO) proposed Guidance on Social Responsibility (ISO 26000) that is due to be published in draft form in October 2009. Edwards (2005) summarizes the various sets of sustainability principles. Typically, these sets differ in their scope (local, regional, national, international) and/or by sector (government, business, industry, or society) to which they apply.

The Natural Step

In 1988, Dr. Karl-Henrik Robert (a practicing clinician and cancer researcher) began the process of developing the principles and objectives that have become known as The Natural Step.

Robert convened a group of over 100 Swedish scientists and asked them to develop a vision for a sustainable society based on the scientific principles. The Natural Step framework (Robert, 1991) was the result of this effort and is becoming widely recognized.

In this framework, there are four underlying principles or conditions and four guiding objectives.

These system conditions are:

1. Nature should not be subject to systematically increasing concentrations of substances extracted from the Earth's crust;
2. Nature should not be subject to increasing concentrations of substances produced by society;
3. Nature should not be subject to systematically increasing degradation by physical means; and
4. People should not be subject to conditions that systematically undermine their capacity to meet their needs.

These conditions can be converted to four objectives that are more easily understood:

1. Eliminate our community's contribution to fossil fuel dependency

and to the wasteful use of scarce metals and minerals;

2. Eliminate our community's contribution to dependency upon persistent chemicals and the wasteful use of synthetic substances;
3. Eliminate our community's contribution to encroachment upon nature; and
4. Meet human needs fairly and efficiently.

To apply The Natural Step, Boisvert et al. (1999) recommend an A-B-C-D approach: Awareness, Baseline Analysis, Compelling Vision, and Down to Action. Kent County chose to align its program with The Natural Step because of its simplicity and scientific basis.

ENVIRONMENTAL MANAGEMENT SYSTEMS

An environmental management system (EMS) is a set of processes and practices that enable an organization to reduce the environmental impacts from its operations and increase efficiency. It helps the organization to systematically manage its environmental "footprint." Alternatively, according to the ISO definition (ISO, 2004) an EMS is "a part of an organization's management system used to develop and implement its environmental policy and manage its environmental aspects." It is built upon the concept of continuous improvement and follows a four element Plan-Do-Check-Act cycle. The EMS is an evolving process and is consistently modified to accommodate new information, changing circumstances and changes in organization priorities.

The critical components of each of the four elements are:

- Planning, includes identifying environmental aspects and establishing goals [**Plan**];
- Implementing, includes training and operational controls [**Do**];
- Checking, includes monitoring and corrective action [**Check**]; and
- Reviewing, includes progress reviews and acting to make needed changes to the EMS [**Act**].

There are a variety of reasons that an organization may develop and implement an EMS. The reasons are many and varied and often depend upon the type

of organization. A business with international offices has different reasons than a public agency to develop and implement an EMS. Table 1 provides a list of the most common of these reasons.

Some disadvantages to developing and implementing an EMS relate to the costs associated with development of the program and include:

- An investment of internal resources, including staff/employee time;
- Costs for training of personnel;
- Costs associated with hiring consulting assistance, if needed; and
- Costs for technical resources to analyze environmental impacts and improvement options, if needed.

Critical factors that assure the success of any management system include:

- Commitment from senior management;
- Designated staff including a Core team to act as a cheerleader and a representative trained in the program;
- Involvement of all employees in the covered fenceline;
- Dedicated resources;
- A link to the overall strategic planning of the organization;
- Sufficient time to develop and implement the program;
- Proper follow through on the checking and acting components; and
- A willingness to make the cultural shift required for the program to succeed.

The ISO 14001 guidance lists 17 elements, shown in Table 2, as the foundation of an EMS.

Several documents and publications cover the various elements of an EMS in detail. One of these is the US EPA publication "Achieving Environmental Excellence: An Environmental Management Systems (EMS) Handbook for Wastewater Utilities," (US EPA, 2004)

INCORPORATING SUSTAINABILITY INTO THE KENT COUNTY FACILITY

The Kent County Regional Wastewater Treatment Facility (KCRWTF) is used as an example to illustrate how sustainability concepts can be incorporated

into the EMS at a wastewater facility. The KCRWTF is a 16 million gallon per day (MGD) biological nitrogen removal (BNR) wastewater treatment plant located in Kent County, DE. The plant treats wastewater from all of Kent County and portions of Sussex and New Castle Counties. Its approximate service population is 130,000. The system serves a mix of residential, commercial and industrial clients, with industrial flow con-

The KCRWTF provides biological nitrogen removal using the Parkson Biolac® treatment system. The water is first treated by screening and grit removal, and flows into one of two 14 million gallon basins where it is aerated, then sent to four clarifiers and disinfected using chlorine gas and then dechlorinated using sulfur dioxide gas. Biosolids are dewatered on belt filter presses, lime stabilized, and indirectly dried. The result-

that the organization has made the commitment to sustainability and that the key principles are in place to guide all future actions. The policy provides the compass that guides the EMS on its journey.

The KCRWTF began its EMS path by participating in the US EPA's Third EMS Initiative for Public Agencies (also referred to as MUNI III). It was one of nine public agencies to participate in the two-year process overseen by the Global Environment Technology Foundation (GETF). The program used the ISO 14001 standard as the model and allowed each agency to define its fenceline (operations to be covered). The KCRWTF chose to include all plant operations and its collection system. Under the program, a Core Team and an environmental management representative were designated to lead the effort.

The EMS Core Team initially developed an environmental policy that was adopted by the Kent County Commissioners for the facility, and that committed the facility to:

- Compliance with all applicable environmental laws and regulations;
- Meeting the National Biosolids Partnership's (NBP) EMS Code of Good Practice;
- Continuous improvement of its EMS program;
- Communicating its vision and EMS program to all interested parties; and
- Promoting pollution prevention.

In 2005, under the direction of the Kent County Commissioners, the policy was revised to address employee health and safety in order to meet the OHSAS 18001 requirements; and this year, a commitment is being added to sustainability principles. This integrated policy is implemented through the KCRWTF Environmental Health and Safety Management Plan (EHS-MP).

Sustainability Aspects, Objectives and Targets

An inventory of the environmental aspects of operations is an important step in the EMS process. In compiling the inventory, the EMS team can use sustainability principles as a means to evaluate their operations and how they impact the environment. By using these

Ensure environmental/regulatory and legal compliance	Required as a part of a compliance settlement
Assist with employee succession and retainage	Improve public image
Save money and other resources	Improve environmental performance
Improve operating efficiency	Obtain a competitive advantage
Provide examples of leadership	Reduce environmental risks
Quality for EPA and other recognition programs	

Environmental Policy	Identifying Environmental Aspects
Legal and Other Requirements	Objectives and Targets
Environmental Management Program(s)	Structure and Responsibility
Training, Awareness, Competency	Communications
EMS Documentation	Document Control
Operational Control	Emergency Preparedness/Response
Monitoring and Measuring	Nonconformance and Corrective Actions
Records	EMS Auditing
Management Review	



principles, the team can focus on more than mere regulatory compliance. These principles help the team to identify all possible impacts.

The sustainability principles can help to establish environmental significance of an operation. The activities that take place within the organization and affect the environment or worker health and safety can be evaluated using sustainability principles. This evaluation indicates which activities or operations have either a positive or negative affect on promoting a sustainable organization. This approach looks upstream at the processes covered and can help the organization assess both local and global impacts on the environment. The alternative that is commonly used is to view only downstream effects and look narrowly at the effects upon the air, land, and water after the process has happened. Consideration of various electrical energy sources is an example of alternatives that could be prompted by looking upstream.

The inventory can be built by evaluating the activities of the organization using the sustainability principles. This might involve evaluating the use of electricity against the first condition of not impacting materials from the earth's crust. Under this scenario, the use of fossil-fueled electric power generation would be a negative aspect. Another objective could involve the use of hazardous chemicals, such as chlorine and sulfur dioxide in a disinfection process, which would be subject to the second condition.

The sustainability criteria can also be applied to rank the operations or activities identified in the inventory according to their significance. The top three to five ranked aspects could then be addressed in the next phase of the EMS.

As a part of the EMS development, the KCRWTF Core Team determined its significant environmental aspects. The three most significant aspects were directly related to The Natural Step's sustainability criteria. They included the use of chlorine gas as a disinfectant and sulfur dioxide gas in the dechlorination process, the use of fuel oil in the biosolids thermal heaters, and the use of fossil-fuel based electricity.

Once the significant aspects have been identified, the organization's EMS must address either how to control them or how to reduce them. Sustainability principles can greatly facilitate the determination and setting of objectives and targets, one of the most important parts of the EMS. In order to be effective, objectives need to be highly specific, measurable, and have a specific target date by which they should be met. They should be in alignment with the environmental policy and vision, and should be established to meet long-term goals, rather than short-term accomplishments. It is important to have a mix of short-term goals and long-term goals with the shorter term goals designed to establish momentum within the program.

A conventional approach to setting management objectives looks at current trends and forecasts future trends to arrive at decisions. This approach takes current trends and projects them into the future.

Under the sustainability principles, a different approach is recommended. This approach is called back-casting and relies on looking at a future where everything is sustainable and then projecting back to the current situation. Back casting was first presented as a part of The Natural Step program. The objectives are then designed to meet the future vision of sustainability.

The Environmental Management Plan

The environmental management plan follows from the established objectives and targets. This plan defines the tasks necessary to meet the objectives within the available resources along with the timetable for task completion. For the KCRWTF, three objectives were developed to address the three most significant aspects identified by the inventory:

- Use of chlorine and sulfur dioxide for disinfection/dechlorination.
- Biosolids drying and management: fuel substitution and kiln combustion
- Use of fossil-fuel based electricity

These objectives were incorporated into their Environmental Management Plan with target dates specified. The KCRWTF Core Team, as a part of its quarterly review, looks over the objectives and targets and determines if sufficient progress has been made towards achiev-

ing them. Once the objectives have been achieved, new objectives are developed to allow for the continuous improvement of the program to move forward.

Substitution of UV for Chlorine and Sulfur Dioxide

The first significant objective to be addressed by the program was to remove the chlorine and sulfur dioxide gases from the plant because of their potential environmental, health, and safety hazards. The chlorine gas system will be replaced by an UV system by the end of 2009. With the elimination of chlorination, the need for dechlorination using sulfur dioxide gas will also be eliminated. The chlorine gas system has been in use since the plant's startup in 1973 and has been extremely safe and reliable. However, because of chlorine's highly hazardous nature and the remote possibility of it being a target of opportunity, it was felt that elimination of the chemical would serve a number of purposes.

The objective was written to reduce or eliminate the use of chlorine gas by 2012. There were a number of steps that were defined in the EHS Management Plan. The first step was to evaluate the options. A Capstone study was conducted by University of Maryland students as a part of their graduate degree program that showed UV as a viable option. The study was reviewed by the Core Team and accepted, and a design engineering firm was selected. Currently, the design process is being finished. The design process selected the Severn Trent Microdynamics® UV system that uses micro-waves to generate the UV radiation.

The facility will be the first in the US and the largest in the world to use the innovative UV system. The Microdynamics® system utilizes UV light bulbs that have no filaments and are guaranteed for three years. Typical UV system providers currently only guarantee their lamps for 1 year. The UV lamps also are at full power within 30 seconds as compared to a typical UV system lamp which reaches full power in 1-5 minutes. This allows the UV system to more easily handle increased flows. The lamps, because they do not have a filament inside them, do not generate clouding of the interior of the lamp tubes and thus prevent the decrease

of the lamp's effectiveness. Decreased effectiveness would require subsequent lamp replacement. The lamps also operate at ambient temperature, which does not allow for a solids build up on the outside of the tubes. The UV system is normally designed based upon wastewater transmissivity. The lower the transmissivity, the less effective the lamps are. The KCRWTF had a measured transmissivity of 75%, which was excellent for the use of UV. A typical secondary treatment effluent transmissivity is between 60-80%. The KCRWTF pilot tested a 1 MGD unit and found that it produced the same level of pathogen reduction that the chlorine system was producing.

As a part of the project, the aeration basin discharges will be redesigned to allow for flow equalization thus ensuring a more constant flow through the UV system. The change to the UV system will save approximately \$100,000 in chemical costs and remove the plant from the US EPA's Risk Management Program (RMP). It will also eliminate the need for evacuation planning around the site and to have a team trained to respond to chlorine leaks. Although the UV system will use electricity, the electricity will be generated by 300 kW of solar photovoltaic panels during daylight hours. This will reduce purchased electricity costs by approximately \$15,000 per year. The expected capital costs for the entire UV/solar project will be about \$4,000,000.

Biosolids Drying and Management

A second objective was to improve biosolids management by substituting natural gas for fuel oil in biosolids drying and by use of some dry biosolids as a fuel in cement kilns. Changing the thermal fluid heaters from fuel oil to natural gas was projected to reduce air pollution by 20%. The fuel oil fired thermal fluid heaters were replaced with natural gas fired units in 2008, and a thermal energy recovery system is being designed for installation in 2009. The switch to natural gas has reduced nitrous oxide emissions by 95%.

In addition, the entire biosolids treatment process is being redesigned. An innovative solar dryer that will treat about 20% of the biosolids is proposed for 2010. This system will dry the filter pressed sludge cake to 85% solids us-

ing passive solar energy as well as heat recovered from the aeration system blowers. The dried biosolids will then be transported to a nearby cement kiln where the cake will be burned in lieu of coal. The revised biosolids process will reduce natural gas usage by approximately 20% and reduce the need for transport trucks and other equipment for land application of Kentorganite on local farms. In addition, the use of polymers and ferric chloride to increase filter press cake solids will be greatly reduced, and the use of lime as a stabilizing agent will be eliminated. However, there will be a reduction in Kentorganite available for the farmers, which would require them to find a more costly alternative for the nutrients and soil amending properties provided by Kentorganite. The use of anaerobic digestion was evaluated, but because the facility does not currently use anaerobic digestion, it is not as cost effective as the solar dryer.

Solar and Wind Power for Plant Electricity

A third significant objective was to move away from fossil fuel fired sources of electricity. The plant is currently planning to design and install a renewable energy facility at the plant which will combine wind, solar, and biomass generation to provide 100% of the needed electricity at the wastewater plant, which is about 30,000 kWh per day or 1.25 MW. The facility intends to install approximately 300 kW of solar electricity to power the new UV system and other portions of the facility by the end of 2009. The remaining major component of the energy facility will be the wind system, which is currently under study. The facility has 4 years worth of wind data at 100', but has just recently installed a three tiered monitoring system that measures wind at 75', 125' and 185'. Once a year's worth of upper level wind data is obtained, it is hoped that there will be sufficient wind to justify the installation of 3-5 MW of wind turbines at the facility. If it proves achievable, the wind system is expected to be installed by 2012. Heating, ventilation, and cooling of the two office buildings located at the facility represents a major use of electricity. A geothermal system that will provide heating and cooling is currently being designed.

Consistency with Natural Step Conditions

A review of The Natural Step conditions shows that the first objective will address system condition number 2 (in a sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society).

The other two objectives will address system condition number 1 (in a sustainable society, nature is not subject to systematically increasing concentrations of substances extracted from the Earth's crust).

Sustainability Training, Awareness and Competency

The training, awareness, and competency program is the element of the EMS where the sustainability principles are communicated to all members of the organization. The KCRWTF holds annual EMS awareness training for all of its employees. In the latest training session, a significant portion of the class was devoted to understanding The Natural Step framework and how the KCRWTF is using it to guide its current programs.

Sustainability Progress Measurement

A common phrase used in business today is "what gets measured gets managed." Progress is measured using the three stated EMS objectives as well as some emerging performance indicators such as product life cycle and carbon footprint. Monitoring of progress occurs during the quarterly Core Team meetings. The EMS representative provides a summary of the progress towards the objectives and goals set forth in the program and the Core Team then uses this information to ensure the programs are progressing as anticipated or if not, what changes need to be made to ensure the programs meet the objectives and targets established by the EMS. In addition, the KCRWTF prepares several annual reports to the US EPA and the public about its EMS activities including its progress towards sustainability.

The KCRWTF was the first publicly owned treatment works to be admitted into the US EPA's National Performance Track program. The Performance Track program required an annual report on progress that includes measureable data on progress

toward objectives as well as a description of the carbon footprint of the facility. Although the US EPA no longer supports the Performance Track program, the Kent County treatment facility will continue to measure progress toward the goals.

SUMMARY AND CONCLUSIONS

1. This paper describes how the Kent County Regional Wastewater Treatment Facility is using the sustainability principles of The Natural Step in conjunction with the ISO 14001 concepts to incorporate sustainability into an environmental management system.
2. Three sustainability objectives incorporated into the environmental management system at the Kent County Facility serve as examples of how sustainability can be implemented at a wastewater treatment utility. These objectives involved substitution of UV disinfection for chlorine disinfection, submission of natural gas for fuel oil, and dried biosolids for coal along with development of solar and wind power for plant electrical needs.

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