11-8-2003

Soil and Water Monitoring for Model Testing and Validation for TMDL Compliance and Nutrient Management

Ramesh Kanwar
Iowa State University, rskanwar@iastate.edu

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Abstract

It is extremely important to have ongoing and continuous water quality monitoring programs in watersheds for national water quality assessment in describing the status and trends in the quality of surface and ground water resources draining to international waters and causing major global water quality concerns that may have human health implications. Extensive soil and water quality programs in watersheds also provide a sound and science based understanding of primary effects of best management systems implemented on the landscape in improving the overall quality of major water bodies in a given region/basin. Since World War II, agricultural production has shifted from highly labor-intensive to machine driven and chemical-intensive methods. The use of the latest technology in farm mechanization, plant and animal production systems, and in the production of new chemicals for insect and weed control has resulted in an abundant supply of food and fiber at a relatively low cost. At the same time during the last 25 years, a serious public concern has emerged about the fate of agrochemicals and their impacts on humankind and the environment (particularly in relation to water quality). This concern was further intensified recently with the detection of many agricultural pollutants in the worlds major water bodies through the use of several environmental monitoring programs worldwide. A number of environmental monitoring programs were initiated in the United States to better understand the movement and the degradation of agricultural pollutants in the soilwater- air system. The results of these soil and water monitoring studies indicate that behavior of agrochemicals in the soil and water system is a complex process influenced by hydrologic and geologic conditions of the region, chemical properties and agricultural production practices. Development of sustainable agricultural production systems will be necessary to safeguard the worlds already damaged ecosystem and water supplies and sound principles of science and technology will need to be applied to minimize environmental degradation. Many technologies are now available to increase the efficiency of machines, nutrients, pesticides, and irrigation water use by adopting appropriate farming systems but the positive role of these technologies on water quality can only be documented by implementing sound soil and water monitoring techniques in watersheds so that good water quality data are collected to assure that nations water supply are safe for human and animal consumption.

Disciplines

Agriculture | Bioresource and Agricultural Engineering | Water Resource Management

Comments

This proceeding is published as Kanwar, Ramesh. "Soil and Water Monitoring for Model Testing and Validation for TMDL Compliance and Nutrient Management." In *Total Maximum Daily Load (TMDL) Environmental Regulations II*, ASAE Publication Number 701P1503 (A. Saleh, ed.).(2003): 80-91. DOI: 10.13031/2013.15541. Posted with permission.

This is not a peer-reviewed article.
Pp. 080-091 in Total Maximum Daily Load (TMDL) Environmental Regulations–II
Proceedings of the 8-12 November 2003 Conference (Albuquerque, New Mexico USA), Publication Date 8 November 2003.
ASAE Publication Number 701P1503, ed. A. Saleh.

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Ramesh Kanwar, Professor and Department Chair
Department of Agricultural and Biosystems Engineering
Iowa State University, Ames, Iowa 50011, USA
E-mail: rskanwar@iastate.edu, Phone : 515-294-1434

ABSTRACT

It is extremely important to have ongoing and continuous water quality monitoring programs in watersheds for national water quality assessment in describing the status and trends in the quality of surface and ground water resources draining to international waters and causing major global water quality concerns that may have human health implications. Extensive soil and water quality programs in watersheds also provide a sound and science based understanding of primary effects of best management systems implemented on the landscape in improving the overall quality of major water bodies in a given region/basin. Since World War II, agricultural production has shifted from highly labor-intensive to machine driven and chemical-intensive methods. The use of the latest technology in farm mechanization, plant and animal production systems, and in the production of new chemicals for insect and weed control has resulted in an abundant supply of food and fiber at a relatively low cost. At the same time during the last 25 years, a serious public concern has emerged about the fate of agrochemicals and their impacts on humankind and the environment (particularly in relation to water quality). This concern was further intensified recently with the detection of many agricultural pollutants in the world's major water bodies through the use of several environmental monitoring programs worldwide. A number of environmental monitoring programs were initiated in the United States to better understand the movement and the degradation of agricultural pollutants in the soil-water-air system. The results of these soil and water monitoring studies indicate that behavior of agrochemicals in the soil and water system is a complex process influenced by hydrologic and geologic conditions of the region, chemical properties and agricultural production practices. Development of sustainable agricultural production systems will be necessary to safeguard the world's already damaged ecosystem and water supplies and sound principles of science and technology will need to be applied to minimize environmental degradation. Many technologies are now available to increase the efficiency of machines, nutrients, pesticides, and irrigation water use by adopting appropriate farming systems but the positive role of these technologies on water quality can only be documented by implementing sound soil and water monitoring techniques in watersheds so that good water quality data are collected to assure that nations water supply are safe for human and animal consumption.

INTRODUCTION

The first and foremost component of a comprehensive environmental assessment policy is that developments are environmentally sound and sustainable. Human activities have affected the various elements of the natural and agricultural environments and the growth in human population on this planet has forced many plant and animal species into extinction. The1995 UN Conference on Biodiversity in Indonesia found that human population growth and economic development are depleting biological resources around the globe. Several thousand plants and animal species are becoming extinct every day from the surface of this planet as this kind of information is becoming available through the monitoring efforts of various groups on "eco-monitoring networks". A recent study conducted in Iowa indicated that destruction of natural habitat from the introduction of intensive agricultural production systems, have been the greatest contributor of Iowa's loss of biodiversity and change in water quality. In order to bring more and more land under intensive agriculture, a large proportion of wetlands and marshes were artificially drained in northwest and north-central Iowa and about 3.08 million hectares of prairie-marsh habitat was reduced to about 10 525 hectares in about 100 years. The drainage of wetlands and their subsequent degradation because of sediment and nutrients in agricultural runoff (the major source of water for many of the remaining wetlands) has resulted in a number of direct and indirect changes in Iowa's water quality. The study further illustrates the value of environmental monitoring to collect information on various environmental and water quality indicators.

The intensification of agriculture has occurred because of increased biological inputs (crop varieties), mechanical inputs (farm mechanization), water inputs (irrigation systems) and chemical inputs (fertilizers and pesticides). The use of agrochemicals such as fertilizers, herbicides, and insecticides has not only increased the crop yields but also has started deterioration of the very base of global food production system i.e. soil and water resources. The development of a hypoxia zone in the Gulf of Mexico is being linked to the production agriculture in the Midwestern parts of the USA. Water drained from agricultural lands in the Midwest has been reported to be a potential source of contamination of water bodies with nitrate-nitrogen (NO_3-N) in the Gulf of Mexico. The Black Sea hypoxia zone is also linked to the agricultural pollution draining from Black Sea riparian countries. The survey of the National Water Quality Assessment Program of the U. S. Geological Survey showed several herbicides such as atrazine, metolachlor, prometon and simazine were detected the most frequently across the United States. Through extensive water monitoring programs, this survey analyzed 2200 samples from 1992 to 1995 from sampling sites that represent 37 diverse agricultural basins, 11 urban basins and 10 basins with mixed land use. Nationally, 11 herbicides, 1 herbicide degradation product, and 3 insecticides were detected in more than 10 percent of the samples. Many of these water supplies contained nitrate-nitrogen (NO_3-N) concentrations greater than 10 mg l^{-1}, a drinking water standard set by the U.S. Environmental Protection Agency (USEPA). Besides NO_3-N, some common pesticides have also been found in the water. Since the first discovery of a pesticide in the groundwater in 1979, 46 pesticides have been found to contaminate groundwater as a result of normal agricultural use. To continue to obtain these kinds of data sets for developing environmentally effective watershed management and policy programs, extensive network on watershed/basin monitoring need to be developed to create baseline data sets for all major river watersheds of the world.

The increased use of agricultural chemicals has contributed significantly to the agricultural productivity but has been the source of much controversy recently because of the perceived health risks posed by the presence of nitrate, pesticide, and other compounds in drinking water. This has resulted in the introduction of groundwater quality legislation by several states in the U.S.A. High concentrations of nitrate-nitrogen (NO_3-N) in drinking water could cause methemoglobinemia (bluebaby syndrome – a temporary blood disorder that reduces the ability of an infant's blood stream to carry oxygen through the body). Some evidence exists that high NO_3-N ingestion is involved in the etiology of human cancer. The negative impacts of the use of pesticides to human health and the environment have been a source of concern. In addition to concern for the acute and chronic toxicity of pesticides, their potential as carcinogens and their presence in groundwater sources have raised questions about their continued use in agriculture. The phosphate-phosphorous concentrations in water bodies at levels as low as 0.05 mg l^{-1} can promote the growth of algae and speed up the process of eutrophication in lakes and reservoirs. Other forms of nitrogen and phosphorous can reduce dissolved oxygen in surface water resources and further enrich the supply of nutrients causing nuisance plant growth. This could happen at any given location of a water body or as far as the international water bodies like the Gulf of Mexico and Black Sea, where "hypoxia zones" are drawing international attention. Another water quality issue is the potential of pathogenic bacteria being transported to the drinking water supply from land receiving animal manure and other municipal and industrial wastes. Therefore, basic and applied methodologies are needed to control, retain, and monitor agricultural and other pollutants in rivers, reservoirs, lakes and groundwater resources. A better understanding of the environmental pollution mechanism is needed to develop simple and rapid monitoring technologies to demonstrate the extent of pollution from current production systems and show how better management practices can further improve the environment. The purpose of this paper is to present various soil and water monitoring technologies that could be used to collect data in response to changes in landscape activities and to monitor the effects of best management practices on water quality and possibly use the water quality data for planning purposes as well as model testing and validation.

SOIL AND WATER MONITORING EQUIPMENT AND PROCEDURES

Soil and water quality can be characterized by the physical, chemical, and biological properties of a given environment (soil, water, and air). A complete assessment in the changes in the salient parameters of soil and water quality by human actions on the landscape will require a well-established soil and water monitoring program. Soil and water monitoring, will refer to those repeated observations, which are the outcome of complex human actions on this planet and their related effects on degradation/improvement of the naturally preserved or humanly disturbed ecological environment. The purpose of environmental monitoring will be to identify and remedy those human activities, which are responsible for soil, air and water degradation in order to protect the human health and well being of the ecological systems. Environmental monitoring should include both source monitoring and ambient monitoring to provide information to establish a cause-effect relationship. An assessment of soil and water quality monitoring program will require reporting of the field data collection procedures and analytical laboratory techniques used, interpretation of data and its use for making management decisions and testing and validating computer simulations models, and recommendation for further actions to implement best management practices on the landscape to correct the environmental damage if any.

Various sources of environmental pollution can be grouped into three categories: i) point sources, ii) nonpoint sources and, iii) mobile sources. The point sources refer to those, which originate from fixed bases or points such as industrial stacks, discharge pipes, and other stationary sources and contribute undesirable effects to the environment. Nonpoint sources are those which originate from large areas such as agricultural lands, or forests whereas the mobile sources of pollution include motor vehicle emissions or spills of toxic and hazardous substances during their transportation. Several sections in this paper will briefly mention the equipments and procedures needed for various environmental monitoring measurements for each environmental attribute. Following are some of the objectives of the soil and water monitoring programs in agricultural watersheds:

- Water quality and nutrient criteria development for rivers, lakes, and wetlands
- Nitrogen (N) and Phosphorous (P) discharge to water bodies – impact of agriculture
- Effectiveness of agricultural management practices in attenuating N and P loadings

- Hypoxia and nonopoint sources pollution from agriculture and animal production
- Local citizen training in controlling nonpoint source pollution – voluntary controls
- Manure management research, BMP's and strategies for pollution control
- Manure handling and Lagoon Construction
- Design strategies for CAFO's for environmental protection
- Water quality monitoring programs for TMDL compliance
- Emerging contaminants (virus, antibiotics, pharmaceuticals, pathogens, endocrine)
- High and low flow impacts on TMDLs
- Water quality regulations
- Implementation plans to control pollution and TMDLs
- Tools (data and models) for TMDL compliance
- Model testing for estimating discharges of nutrients, sediments, bacteria, pesticides and antibiotics from agricultural and non-agricultural watersheds
- Testing and use of field and watershed scale models as management tools
- Policy and legislative issues (nutrients, manure handling, lagoon construction, CAFO sizing, TMDL's)
- To determine water quality benefits of clean water and policy incentives
- Carrot and Stick approach in implementing best-BMP's in agricultural watersheds
- Voluntary efforts in watersheds in response to economic and technical assistance
- Riparian and aquatic ecosystem rotation research
- Environment stewardship
- Social/economic/technical aspects of wetland design and construction
- Monitoring Wetlands – a tool for nutrient and sediment removal
- Wetland regulation and mitigation
- Educational programs for global water technology dissemination
- Inter-state/inter-country watershed research project

METHODS AND EQUIPMENT FOR SOIL AND WATER MONITORING

A. Water Monitoring

Freshwater is a finite resource and is becoming increasingly scarce in many parts of the world because of its usage and exploitation. To meet the growing demands of fresh water, it is being pumped from underground aquifers at a much faster rate than its replenishment rate. Similarly reservoirs and canals are being constructed to store and use water from rivers, which are causing problems of waterlogging and salinity. Moreover, nonpoint source pollution of water has been recognized mainly from the agricultural sector in comparison to any other activity on the landscape. Pollution of major water bodies from point sources such as dumping of untreated municipal and industrial wastes directly to water bodies is probably one of the largest sources of environmental pollution.

Water is never at rest at any place or at any time. Therefore, its environment is an interaction of many complex physical, chemical and biological factors that determine its quality. In order to develop water pollution control programs in the watersheds, the remedial measures should be designed based on these factors. A water quality monitoring program can be a process of observation, analysis and interpretation and this information can be used to conserve natural resources. Water quality monitoring programs can be the foundation for making decisions related to water quality management. In reality, these programs should be based on state, national or international constraints and demands. Therefore, some of the key **objectives of water quality monitoring** programs on a project scale should include monitoring of the following parameters:

i) Water usage status: Is the quality and quantity of water satisfactory to meet the criteria of user's requirements? What is the future status of water use, for example in the next few years?

ii) Water impacts: What are the effects of human activities on water and how does water contribute to pollutant transport from one place to another or from one water body to another?

iii) Water regulations and standards: Does the degree of contamination of water warrant any regulation or management actions for its prevention? What is the status of water with reference to water standards?

iv) Spatial distribution of water quality trends: How much area is affected by water contamination and what are the contamination levels?

v) Pollutants and their sources: The use and identification of various water pollution sources need to be listed. What kinds of pollutants are there and what are the sources of these pollutants? Why are these pollutant sources being used or produced in the watershed?

Although major sources of water pollution arise from human interventions, many natural events can cause environmental degradation of the ecosystem at local level. Therefore, the following considerations are needed for establishing water-monitoring programs for various water bodies.

Selection of Sampling Sites and Equipment: The location or selection of the sampling sites for water quality monitoring programs should take into account the monitoring objectives, the processes affecting spatial and temporal variability in water quality, topography and geology of the area, geography of the water course systems and geological structures within the area. The site selection criteria for water monitoring may differ from location to location depending on the sources of pollution and land use activities. Site selection for installing water monitoring devices must meet the objectives of the data gathering program so that effective implementation of best management practices in the watersheds can lead to an improvement in water quality.

i) ***Groundwater flow and quality measurements:*** Observation wells or dug wells, which are already existing, can be potential sampling sites if they meet the criteria of investigation such as water sampling depth and are representative sites within the watershed activity to be monitored. Springs can also serve as sampling sites provided contamination sources feeding into those spring waters can be identified. The monitoring of unconfined aquifers or confined aquifers can also be performed by installing piezometers at different depths and locations within the landscape to monitor the groundwater depth as well as pollutant movements and their flow directions in a given aquifer system.

ii) ***Surface runoff/stream and river flow and quality monitoring:*** Hydraulic Flumes or other automated flow and quality measurement devices are available to monitor the quality and quantity of surface flows in fields, streams, rivers etc. The most important part of surface flow monitoring is selection of sampling sites where flow monitoring devices can be installed. The selection of sampling sites along the river should be based on the location of various streams or drainage waterways draining water from land use activities in watersheds and joining the river so that river water quality indicators can be compared keeping in mind the pre-and post-effluent entry effects on water quality. Bridges can be good sampling sites because the installed gages can also provide information about flow rates at the sampling time.

iii) ***Lakes/reservoirs:*** The sampling sites for lakes and reservoirs may depend on the size and shape of the water body. The location of incoming and outgoing tributaries should also be considered.

Lake stratification in the vertical direction should be considered because it affects water quality. The samples collected from the selected sites should represent the entire lake water quality or the degradation rate of lake water. Usually sample collection with a boat using global positioning system (GPS) technology can enable the sampler to locate the same position for the next sampling time to maintain the quality control and quality assurance protocols.

Sampling Frequency: The frequency of sampling will depend on the spatial and temporal variation in water quality parameters within a given water body depending on land use activity. Sampling frequency will be low for deeply confined aquifers because of slow water movements within aquifers and relatively slow change in water quality indicators. Surface runoff or river water can be sampled either on a storm basis or on a time basis. Monthly observations may be satisfactory for long term analysis from shallow and deep streams/rivers, drainage ditches and reservoirs. Event by event basis or weekly/monthly may be satisfactory on a long-term basis. Weekly or daily observations can also be made if flow variation in the river is rapid and river water quality is affected by seasonal cropping activity in the watershed.

Selection of Monitoring Variables: The selection of monitoring variables (Tables 1 and 2) will depend on the objectives of environmental monitoring programs and available resources to implement the monitoring program. We must try to use the resources effectively to collect quality data on various environmental parameters. There are three main categories under which different environmental quality parameters can be grouped:

i) **Physical Parameters**

- Water quantity measurements, aquifer yields, rainfall intensity and amounts, flow rate and volumes etc. The various flow attributes will include: velocity, discharge, water level
- General variables (temperature, color, odor, total suspended solids)

ii) **Chemical Parameters**

- Conductivity, pH, acidity, alkalinity
- Biochemical oxygen demand (BOD), dissolved oxygen (DO)
- Nutrients (nitrogen and phosphorous compounds) and antibiotics
- Toxic compounds (insecticides and herbicides), industrial and municipal organic

iii) **Biological Parameters**

- Aquatic life and fisheries
- Fecal coliforms, virus, and other bacteria

Equipment used for Water Monitoring

Groundwater: Confined aquifers are less vulnerable to pollution than unconfined aquifers because vertical percolation of water through impermeable layers is significantly lower than in unconfined soil layers. Confined aquifers are usually deep and water quality is usually considered better than most of the unconfined aquifers. Monitoring of daily water table depth in the unconfined aquifer can be made using observation wells or dug wells because the top of this aquifer is the upper saturated water level called water table. Observation wells may be screened to avoid caving. Sufficient pumping of water from an observation well is usually required before water sample is collected for water quality purpose.

Installing piezometers deeply enough, in the confined geologic formations to monitor water and pollutant movements, can monitor confined aquifers. A piezometer is a small diameter pipe with an open bottom and its installation arrangement prevents any sort of leakage from the sides of the pipes (see the schematic figure 1a below). Piezometers show the hydrostatic pressure at the bottom of the pipe and their network can help in detecting the groundwater flow directions and delineating the areas of recharge and discharge. The density (number required) of piezometers depends on the size, geology and landscape of the area.

Water level in the observation wells or piezometers can be measured by different methods ranging from a wetted tape method to electronic water level loggers or electronic or pneumatic transducers, which can measure and record water levels on an hourly basis throughout the year. Water samples can be obtained from observation wells and piezometers for water quality analysis. Groundwater quality maps can be prepared showing flow directions, areas of recharge/discharge, and pollution and management plans can be prepared accordingly to minimize the potential for groundwater degradation.

Subsurface Drainage Water: Artificial subsurface drainage is necessary in certain areas of the world to maintain the sustainable productivity of poorly drained soils. The installation of subsurface drains ensures timely removal of excess water, during periods of intensive rains, from the root zone but it may also enhance leaching of nitrate-nitrogen (NO_3-N), phosphorous-phosphate (PO_4-P), herbicides, and bacteria to shallow groundwater out of the root zone. The excessive leaching of NO_3-N from agricultural land causes economic loss to the farmers and environmental concerns to public health. Therefore, monitoring the quality of subsurface drainage water for various chemicals and bacteria is important to develop sustainable farming practices.

Typically, four types of subsurface drain flow monitoring systems have been used for water quality studies: (1) weirs or flumes with stage recorders, (2) sump pump with flow meters, (3) tipping buckets, and (4) ultrasonic flow measurement instruments. Weirs and flumes can collect continuous subsurface flow data for water quality analysis but takes a long time to read data from flow charts. Both tipping buckets and sump pumps collect data at discrete flow intervals but provide the convenience of collecting continuous data using the data loggers. The ultrasonic flow measurement system has been used for drain flow measurement but requires precise maintenance. One advantage of a sump pump system, however, is that water does not have to flow by gravity from the plots to an outlet as for weirs, flumes or tipping buckets. The sump pump system requires little maintenance and works well most of the time and is not very expansive to install. The sump pump system with an orifice outlet allows continuous and composite water samples to be collected for water quality analysis. The sump pump system requires about 0.4 m diameter PVC air duct tubing with sealed bases and 110 V powered sump pump, check valve, flow meter and quick release couplers. A data logging system of Neptune T-10 flow meters with rotating disc measuring chambers, analogue registers and Tricon/E transmitters can be mounted on the meters. Continuous water samples for water quality analysis can be collected using an orifice tube located on the discharge pipe. Approximately 0.2 percent of the water pumped from the sump pump flows through a 5 mm diameter polyethylene tube to a water sampling bottle located in the collection sump. A detailed description and layout for an automated system for monitoring the quality and quantity of subsurface drain flows has been reported.

River Water: The estimation of a chemical load passing through a certain cross section of a river requires measurement of the concentration of that chemical and the flow rate of river at that time. The flow rate of river (volume of water flowing per unit time) may be estimated by slope-area method using the Manning equation, which needs information on water area, hydraulic radius and slope of the river bed. Flow rate can also be determined using stage-discharge relationship (rating curve) for a certain cross-section of the river but periodic verification of the rating curve should be made particularly for sites having unstable cross-sections (Figure 1).

Stream flow can also be estimated by measuring the cross-sectional area and flow velocity for that section. The cross-sectional area of the stream can be measured by dividing the flow area into sections and average flow velocity in each cross-section can be measured using a current meter. A float method of measuring flow velocity can be used in case a current meter is not available. Proper care is required in selecting the sites for flow measurement while keeping in mind the straightness of the section, and having a regular/stable bed.

Figure 1. An automated surface water quality monitoring system

Reservoirs/Lakes: Measurement of water level is important during sampling from the lakes/reservoirs. These measurements can be made with official gages. Temporary measurements can also be made with fixed landmarks located on the stationary rock or outcrop. In case of waves, both upper and lower levels should be recorded. Flow velocities in the lakes are usually measured with sensitive recording current meters. Water samples should be obtained close to the inflow and outflow sections of the lake. A surface boat can also be used to obtain water samples at different locations of the lake.

Stratification is common in lakes because of differences in temperature leading to differences in density and partially due to different solute concentrations. Temperature measurements in the lake must be made *in situ* because the sample will reach the surrounding temperature very soon. Temperature can be measured with a glass thermometer or with an electronic thermometer, which is an integral part of the conductivity and dissolved oxygen meter. One of the major researchable topics is the health of lakes in terms of aquatic life, sediments, chemicals, bacteria and siltation. Suspended sediments in the lakes or reservoirs can be measured with four main types of samplers:

i) **Instantaneous samplers:** these samplers can obtain samples instantly

- **Vertical pipe**: sample is collected in the pipe by lowering it in the water
- **Instantaneous vertical/horizontal pipe**: vertical/horizontal cylinder is equipped with end valve to collect sediment water samples instantaneously

- **Pumping**: sucks water-sediment mixture through a pipe.
- **Bottle**: simplest sampling device

ii) **Integrated samplers**:

- **Time integrating**: collect samples at one depth over an extended period of time
- **Depth integrating**: collect samples during the lowering of a bottle in the stream to integrate the depth.

iii) **Automatic samplers**: These samplers overcome the difficulties encountered during operation of the above mentioned samplers but these samplers are restricted to sediments having a size smaller than 62 microns.

NO_3-N, Phosphorus and Silica Analyses: Phosphorus and N in water and soil can be assessed in the chemical laboratory using standard methods. In runoff water, P can be analyzed as total P and total soluble reactive P. Total P can be determined after acidification and digestion and soluble reactive P can be determined without digestion. Silicon in water can be assessed as total silica and molybdale-reactive silica. Total silica can be determined gravimetrically. Silica loss from manured fields to water bodies is becoming an area of interest to researchers as it is considered a source of pollution. Nitrate-nitrogen concentrations in water samples can be analyzed spectrophotometrically using a Lachat Model AE ion analyzer. For soil samples, NO_3-N can be extracted from soil using potassium chloride and analyzed using the Lachat Model AE ion analyzer. Several other simple techniques are also available including nitrate electrodes.

Fecal Coliform Bacteria- sample collection and enumeration: The method of sample collection for enumeration of bacteria can be done aseptically. Surface runoff, river water, lake water, and subsurface drainage water samples can be collected in sterile plastic bags in order to eliminate any cross contamination between samples and can be stored immediately at a temperature of 4^{o}C. The water samples can be plated on selective media and can be analyzed within 24 h of their collection.

Water samples can be analyzed for fecal coliform and fecal streptococcus bacteria. The sample procedures, including collection, storage, and analysis for the determination of fecal coliform and fecal streptococcus can be conducted according to the Standard Methods for the Examination of Water and Wastewater. Determinations of densities of fecal coliform bacteria in the water sample can be done using the Membrane Filter (MF) technique. The MF technique is highly reproducible and can be used to test relatively large volumes of sample, and yield results rapidly. Sample volumes of 100, 50 and 10 ml can be filtered through a 0.45 μm sterile membrane. These filters can then be transferred to M-FC medium in a petri dish, avoiding air bubbles beneath the membrane. These culture plates can be inverted and incubated for 24 hours at 44.5^{o}C in a constant temperature water bath. The colonies can be counted after 24 hours of incubation. The colonies produced by fecal coliforrn bacteria can be blue in color. The density of fecal coliforms can be recorded in terms of colony forming units (cfu per 100 mL^{-1}). Colonies can be counted using the membrane filters with 20 to 80 colonies. The colonies can be counted by multiplying the total number of colonies per plate by the reciprocal of their dilution. If the total number of colonies exceeds 200 per membrane, then they can be reported as too numerous to count (TNTC). If the membranes contain less than 20 colonies, then an approximate estimate can be recorded.

B. Soil Monitoring

Soil refers to that portion of the earth's crust where plants are grown and is considered to be a living dynamic complex system. Soil is formed as a result of physical, chemical and biological processes, which are driven by complex interaction of climate, parent material, topography, organisms, time, and human activities. The soil properties vary in horizontal as well as in vertical directions because the factors forming them are varying over space and time domains. An ideal soil comprises of 45 percent mineral, 5 percent organic matter and living micro-organisms and 50 percent voids. Soil can be considered as a reservoir, which meets the demands of the organisms, living on its surface, directly or indirectly. Humankind has exploited soil resources to feed the growing population using intensive agricultural production systems. The interaction of human activities and the changing climate has started degradation of this resource resulting in erosion, salinization and chemical contamination. Soil is a finite resource and its sustainability needs to be promoted through soil monitoring programs by knowing the actual damage due to soil quality and health on an annual basis.

Soil Quality: The use of agrochemicals has greatly increased agricultural production but at the same it has started degradation of soil and water resources. Many studies have reported increased nitrate-nitrogen (NO_3-N) and phosphorous-phosphate (PO_4-P) concentrations in stream water and in deep groundwater resources due to higher application rates of nitrogenous and phosphorous fertilizer. Leaching of NO_3-N from the soils are due to accumulation of residual soil NO_3-N in the root zone, which indicates economic inefficiency for farmers and nonpoint source pollution for the environment. Similarly, use of pesticides has become an integral part of the high yield input package despite their negative effects on the environment. Today, more than 500 different formulations of pesticides are being used in our environment and agriculture holds the largest single share of pesticide use. Several studies have indicated that surface applied chemicals can be rapidly transported to the deeper soil depths and even to shallow groundwater systems. In this context, soil monitoring programs need to be developed for sustaining productivity of soil resources and maintaining a healthy environment.

Soil Salinity: Salt affected soils are found in every continent and are estimated to be about 7 percent of the lands of the world. Soil salinization refers to accumulation of salts in the soil to such an extent that soil productivity and crop yields are affected. Soil alkalinity occurs due to a high degree of soil saturation with sodium. The main factors contributing to soil salinity are climate, soil type, geomorphology, hydrology, topography, and irrigation practices. Irrigation also adds salts to the soil even if the soil is of excellent quality. Soil salinity starts building up when salt accumulation exceeds salt removal in the root zone. The worst condition may happen when the watertable starts to rise and brings salts from lower soil layers to the root zone where water may evaporate leaving the salts at the soil surface. Therefore, the mechanism of salt accumulation and their sources need to be identified before designing reclamation techniques. To avoid salinity hazards, leaching of salts from the root zone should be practiced at a time when evapotranspiration demands are lower particularly during the rainy season. Salt balance analysis of the root zone should be carried out to estimate the rate and sources of salt accumulation in the root zone for proper planning of soil reclamation strategies. Monitoring of salinity levels of irrigated lands is an essential element of water management. Salinity levels can be measured either using salinity sensors and determining the contents of Na, Ca and other anions.

Figure 2. Zero contamination tubes for soil quality monitoring

Soil Sampling: Several, 120 cm long soil cores can be collected from a given field using a hand sampler before chemical applications and planting time (early April) in the spring and after harvest in the fall (later October). Several different types of soil samplers are available but more recently a 2.5 cm diameter plastic liner has been used inside the soil sampler to protect the soil from contamination. Soil cores are promptly frozen after collection. Prior to analysis, the three cores from a given plot are cut, into sections representing different depth increments such as 0 to 10, 10 to 20, 20 to 30, 30 to 60, 60 to 90 and 90 to 120 cm (Figure 2). These soil samples are wraped in an aluminium foil and are sent to the laboratory for N, P, soil moisture analyses, pesticides, and bacteria analyses. This type of sampling procedure ensures quality control.

Table 1. Soil and water quality monitoring parameters in water quality monitoring project

Purpose of Analysis	Analytical Parameters	
	Soils	Surface and ground water
General Characterization	Organic matter color texture pH hydraulic conductivity of soil profiles	PH Turbidity Odor Dissolved solids suspended solids hardness, etc.
Water and soil quality hazard	i) Organic-N NO_3-N P, K herbicide residues fecal coliform from animal waste ii) Heavy metals: B, Zn, Li, Cu, Fe, Cd, Hg, Al, Pb, and other heavy metals such as Arsenic, Selenium, Chromium	i) Dissolved organic N, ortho and total P, Herbicides Insecticides and other pesticides used in the area fecal coliform from animal waste ii) Heavy metals: B, Zn, Li, Cu, Fl, Cd, Hg, Al, pb, and other heavy metals

	iii) Oils and greases iv) Radioactive materials	iii) Oils and greases iv) Radioactive materials
Salinity Hazard	Ec, Ca, Mg, Na, CO_3 HCO_3, SO_4, Cl	Ec, Ca, Mg, Na, CO_3 HCO_3, SO_4, Cl
biological for biodiversity, fauna & Flora	micro-organism respiration plant life etc.	E-coli Algae other plant life

Table 2. Environmental Action Plan for water quality projects: Environmental Impacts.

Issues	Anticipated Potential Impact	Effect	Actions
Surface water quality	i) Deterioration in quality as runoff waters from swine and cattle manure disposal sites, and agricultural areas treated with manure and agricultural chemicals join river & other surface water bodies which evetually drain to Black Sea. ii) Runoff waters containing unknown chemicals from FSU times and recently imported cheaper chemicals join river waters to deteriorate the quality. iii) increased soil erosion deteriorates the quality of surface waters. iv) Oils, greases joining surface waters to affect water quality **Probability of occurrence: High**	i) Decreased utility of Black Sea coastal waters will result in less use of beaches by public and decreased harvest of good quality fish ii) Decreased utility of water for downstream users and fisheries if any. iii) drinking water supplies will get contaminated	Undertake a rigorous water quality monitoring plan of river waters that drain into Black Sea to establish a baseline database of the quality of river waters, lakes and shoreline water of Black Sea.
Groundwater	i) water quality deterioration as a result of leaching of agricultural chemicals and nitrogen and bacteria from manure ii) water quality deterioration from leaching of salts from the selected areas . **Probability of occurrence: Moderate**	Decresaed availiability of water for human and animal consumption	i) Regions monitoring of ground water in highly intensive agricultural and animal production areas. ii) Sample selected drinking water wells once a month. iii) Monitor groundwater quality in watersheds with improved farming systems (conservation tillage etc.) to control soil erosion and improve water quality
Soil Quality	With the introduction of better farming systems, soil quality will improve **Probability of occurrence: high**	Better productive lands	Undertake soil monitoring of selected areas to establish the ffect of better farming systems on soil quality
Biodiversity	Increased biodiversity will occur because of introduction of conservation tillage systems. **Probability of occurrence: high**	Increased biodiversity	Undertake baseline survey of fauna and flora in the project area. Monitor impact of plant and animal populations, measure microbial activity