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Title

A water quality testing system

Technical Field

The invention concerns a testing system for continuous sampling and testing of effluent at a water treatment plant.

Background of the Invention

Integrated sampling and monitoring systems for waste chemical treatment processes are not available. However, basic chemical analysis and sampling systems exist. US 4,108,602 [Hanson] and US 5,029,484 [Somers] disclose such systems.

Hanson discloses an automated sample changing chemical analysis system for sequentially analyzing a series of samples such as pharmaceutical chemical samples. A pressure/vacuum source withdraws each sample from its respective source in sequence through a sample selector valve and transports the sample to the flow cell of a chemical analyzer such as an UV spectrophotometer. It then returns all or part of the sample to its source through the same selector valve and purges the flow cell and conduits back to the sample source. Each sample is drawn by vacuum from its source through the selector valve into the flow cell. The entire sample is returned after analysis by air pressure back through the selector valve to the source. Alternatively, diluents or a reagent is mixed with the sample in an intermediate step to bring the sample within the testing range of the analyzer. Micro-porous filter stop means is employed to protect the pressure/vacuum source from system liquids. This also is used to accurately measure the quantity of diluents or reagent to be mixed with the sample, and to minimize bubbles in the system.

Somers discloses a device and method for collecting a representative sample of hazardous fluid from a drum. The sampling device is disposed without ever removing the sampling device from the drum to safeguard the operator from exposure to the hazardous fluid. The collected sample is moved by a slidable plunger along the inner channel of a hollow tube toward a drainage opening while the bottom of the tube remains immersed within the tank. A break-apart



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construction of the sampling device enables separation between its immersed and emergent portions. The tube remains immersed to safeguard the operator after sampling has been completed. The separated portions in the drum being sampled are permanently disposed of. An irreversible plunger movement feature discourages any attempt to reuse the sampling device.

The prior art is unable to sample and monitor waste chemical automatically in an integrated form and unable to comprehensively measure an adequate range of environmental parameters.

Summary of the Invention

In a first preferred aspect, there is provided a testing system for continuous sampling and testing of effluent at a water treatment plant, the system comprising:

a sampling system to collect samples of the effluent;

a monitoring system connected to the sampling system, for measuring environmental parameters of the samples, the monitoring system comprising:

a first analysis chamber for measuring environmental parameters of at least two selected from the group consisting of: pH, oxidation reduction potential (ORP) value for state of reduction oxidation (Redox), conductivity value for total dissolved solids (TDS), dissolved oxygen (DO), turbidity (Tu) value for suspended solid (SS) and temperature (T);

a second analysis chamber for measuring the concentration of anions in the samples using a plurality of ion selective electrodes (ISEs); and

a third analysis chamber for measuring the concentration of heavy metals in the samples using anode stripping voltammetry (ASV); and

a control system to control the collection of samples by the sampling system, to control washing and rinsing of the analysis chambers, and to record the measurements obtained by the monitoring system.

Advantageously, the present invention minimises contamination and reduces the time taken to measure the samples.

The first, second and third analysis chambers may perform measurements concurrently.

The samples of the effluent may be collected from one or more treatment tanks of the water treatment plant. The samples may be collected sequentially.

Each chamber may comprise a stirring device to mix the samples.

The first analysis chamber may comprise a temperature probe, pH probe, ORP probe, conductivity probe, DO probe and turbidity probe, for measuring the environmental parameters.

The ion selective electrodes (ISEs) may include a chloride ISE, fluoride ISE, cyanide ISE and a sulfide ISE.

The anode stripping voltammetry (ASV) is performed by an ASV device. The ASV device may comprise a working electrode, a counter electrode and a reference electrode.

The sampling system may comprise:

a first sampling module to direct a first sample collected from a first treatment tank to the monitoring system via a sampling pipe; and

a second sampling module to rinse the sampling pipe with a second sample for until completion of the first sampling module.

The sampling modules may be connected by a switchover solenoid valve. Each sampling module may comprise a diaphragm pump, a cross-flow membrane filter, a differential pressure transmitter, a manual control valve, an inlet solenoid valve and an outlet solenoid valve. The pump may be actuated to rinse the sampling pipe of the sampling modules for a predetermined time period. The cross-flow membrane filter may have a membrane to block particles larger than a predetermined membrane hole size.

The monitoring system may further comprise a titration assembly, calibration assembly, washing assembly and a disposal assembly.

The washing assembly may include a container containing a chemical cleaning liquid. The chemical cleaning liquid may flow into any one of the chambers to wash the respective chamber. The washing assembly may also include a container containing clean water. After washing, the clean water may flow into any one of the

chambers to rinse the respective chamber. Rinsing may be performed more than once.

The disposal assembly may include a disposal tank to receive drainage of the samples, chemical cleaning liquid and clean water from the chambers. The disposal tank may comprise a level switch, diaphragm pump, and solenoid valves to direct the sample to a specific treatment tank. The disposal tank may comprise a conductivity level switch having three electrodes, to control the drainage volume in the disposal tank between a high level and a low level. If the high level is reached, the pump may be activated to return the drainage to the treatment tanks. If the low level is reached, the pump may be deactivated.

The titration assembly may comprise a container to contain titration solution to simulate the treatment process in the testing system.

Brief Description of the Drawings

An example of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a testing system according to the preferred embodiment of the invention;

Figure 2 is a block diagram of the monitoring system;

Figure 3 is an illustration of a cross-flow membrane filter to produce particulate-free samples for the monitoring system;

Figure 4 is a detailed side view of the MF chamber of the monitoring system;

Figure 5 is a detailed top view of the MF chamber;

Figure 6 is a detailed side view of the ISE chamber of the monitoring system;

Figure 7 is a detailed top view of the ISE chamber;

Figure 8 is a detailed side view of the HM chamber of the monitoring system;

Figure 9 is a detailed top view of the HM chamber;

Figure 10 is a detailed side view of the disposal tank; and

Figure 11 is a detailed top view of the disposal tank.

Detailed Description of the Drawings

Referring to the drawings, a testing system 10 generally comprising a multi-stream sampling system 20, a monitoring system 40 and a control system 80 is provided. The testing system 10 performs online testing of a plurality of treatment tanks 5 in a water treatment plant (not shown). The multi-stream sampling system 20 draws sample solutions from treatment tanks 5 via sampling pumps. The sample solutions are drawn through a filter and directed to the monitoring system 40 in a sequence. The monitoring system 40 measures chemicals and environmental variables of the sample solution. Once the measurements are taken, the sample solution is drained to a disposal tank 48 and pumped back to the treatment tanks 5. The operation of the solenoid valves, pumps and other instruments of the multi-stream sampling system 20 and the monitoring system 40 are controlled by the control system 80.

Multi-Stream Sampling System

Referring to Figure 1, the multi-stream sampling system 20 is placed between the treatment tanks 5 and the monitoring system 40. In one embodiment, there are eight treatment tanks 5. The multi-stream sampling system 20 is composed of two sampling modules. Each sampling module has the same structure and components. During the normal operation, a first sampling module collects a sample from one treatment tank 5 and directs the sample to the monitoring system 40. The second sampling module pumps the waste chemical from another treatment tank 5 to flush the sampling pipe. This replaces the prior sample with a new sample in order to prepare for monitoring of the next sample. The "one-run and prepare" sampling system 20 can shorten the sample delay from treatment tanks 5 to the monitoring system 40, minimize the contamination of each sample and reduce measurement time.

Both sampling modules connect the treatment tanks 5 to the monitoring system 40. Each sampling module includes a diaphragm pump 23, a cross-flow membrane filter 30, a differential pressure transmitter 25, a manual control valve 26, an inlet 21 and outlet solenoid valve 22, and a switchover solenoid valve 27.

Referring to Figure 3, the cross-flow filter 30 has a membrane 31 such that particles larger than a predetermined membrane hole size are blocked. In one example, the predetermined membrane hole size may be two μm. In cross flow filtration, the slurry flows tangentially across the filter medium 31 while the filtrate permeates the septum vertically. The high tangential flow rate of bulk solution removes most of the sludge effectively. The accumulation of sludge across the surface of membrane 31 is also reduced. The operational lifetime of the cross-flow filter 30 is longer than a dead end filtration scheme. In the multi-stream sampling system 20, the cross-flow membrane filter 30 is used to remove particles in the sample fluid, and protect the probes of the chemical sensors in the monitoring system 40 from fouling and damage.

The differential pressure transmitter 25 is used to measure the pressure drop between inlet 32 and outlet 33 of the filter 30. When the filter 30 is blocked by sludge, the pressure drop of fluid passing through the filter 30 increases. If the pressure drop exceeds a pre-set limit, the control system 80 raises an alarm to remind the operator to service the filter 30.

The operation sampling cycle of the testing system 10 includes several stages: (1) rinsing the sampling pipe, (2) collecting and monitoring the sample, (3) switching to other samples in other treatment tanks 5.

Stage 1 is executed only at the beginning of the sampling process. Stages 2 and 3 are executed repeatedly until the sampling process is terminated. Before starting the sampling operation, all the automatic valves are closed and pumps are shut down. The operator selects the treatment tanks 5 to be sampled and monitored (for example, all treatment tanks 5 may be monitored). The inlet 21 and the outlet solenoid valves 22 of treatment tanks 5 are opened. Then, the sampling pumps 23 are actuated to rinse the sampling pipe of the two sampling modules for a predetermined time period. During rinsing, new samples from the treatment tanks 5 completely replace old samples left in the sampling pipe. This minimizes the contamination among the different samples. When rinsing is completed, one of the switchover valves 27 is turned on. The filtrated sample from the treatment tank 5 flows into the monitoring system 40 at a substantially constant flow rate. When the analysis chambers of the monitoring system 40 are filled up by the filtrated sample,

the valve 27 is closed. The monitoring system 40 starts to measure the chemical and environmental parameters in the analysis chambers. After the monitoring process of treatment tank 5 is finished, the inlet 21 and outlet valves 22 of treatment tank 5 are closed, and the inlet 21 and outlet valves 22 of another treatment tank 5 are opened. Then, the group switch valve 27 is opened. Thus, the filtrated sample from the treatment tank 5 enters the monitoring system 40 and the sample from the treatment tank 5 is pumped to rinse the pipe. The sampling procedure continues repeatedly until the operator terminates it.

Monitoring System

Referring to Figure 2, the monitoring system 40 comprises three analysis chambers 41, 50, 60 which may run concurrently. The analysis chambers are the MF chamber 41, Ion Selective Electrode (ISE) chamber 50 and HM chamber 60. Each analysis chamber has multiple probes which are able to perform environmental parameter monitoring, sample titration for treatment prediction, probe calibration, probe and chamber washing and analyzed sample discharge. Each analytical chamber 41, 50, 60 also has a mini-stirrer and level sensors.

[1] MF Chamber

Acidity (pH), oxidation reduction potential (ORP) value for state of redox, conductivity value for total dissolved solids (TDS), dissolved oxygen (DO), turbidity (Tu) value for suspended solid (SS) and temperature (T) are six important environmental parameters for determining the quality of waste chemical and wastewater treatment. Sensors to monitor these parameters are provided for quality control. These sensors are selected and installed in the MF chamber 41. Eight chemical containers 44 are coupled to the MF chamber 41. Four containers hold standard chemical solutions for pH and ORP calibration. The other four containers hold standard chemical solutions for pH and ORP titration. All the chemical containers 44 are located about 40 centimetres higher than the MF chamber 41. At the bottom of each chemical container there is a solenoid valve 45. When the solenoid valve 45 is open, the chemical is able to flow into the MF chamber 41 from the chemical container as a result of gravity.

Referring to Figures 4 and 5, six sensors 400 are installed near the bottom of the MF chamber 41 to minimize chemical consumption during calibration and titration. These sensors 400 include a temperature probe, pH probe, ORP probe, conductivity probe, DO probe and turbidity probe. A motor 42 is installed on the top center to drive a small stirrer inside the MF chamber 41 to mix the solutions. A conductivity level switch 401 with four electrodes 402 is also installed to control the sample level at three setting points. All inlets coupled to the MF chamber 41 are connected to a manifold such that only one pipe is coupled to the MF chamber 41 directly. The MF chamber 41 has an overflow pipe to prevent it from abnormal level sensor conditions. It also has a drain in the bottom to empty the MF chamber 41 completely according to operating requirements. The MF chamber 41 has several different operational modes including sample measurement, titration and calibration as well as chamber washing and discharge.

To commence measurement, a sample inlet valve 46 and a drain valve 43 are opened to let the sample flush the MF chamber 41 for a predetermined time period to replace the solution left by a prior sample. Next, the drain valve is closed, and the sample from the multi-stream sampling system 20 flows into the MF chamber 41. When the sample level reaches a predetermined level, the inlet valve 46 is closed and the stirrer 42 is actuated. The sensors in the MF chamber 41 then begin to measure the environmental parameters of the sample. Once the control system 80 obtains stable signals from all six sensors, the value of variables are shown and recorded in the control system 80. If signals from the sensors are not stable after a predetermined time period, measurement is stopped and an alarm is raised to remind the operator to check whether the sensors or other instruments are faulty. The stirrer 42 is stopped, and the drain valve 43 is opened for a predetermined time period to completely empty the MF chamber 41. Now, the MF chamber 41 is ready to measure the next samples.

Online pH and ORP titration is used to simulate the treatment process in the testing system 10. It is also used to identify chemicals, such as acid, alkaline, oxidant and reducer, and consumption to optimize the treatment process. To start titration, the sample inlet valve 46 and the drain valve 43 are opened to let the sample flush the MF chamber 41 for a predetermined time period to replace the solution left by a prior sample. Then, the drain valve 43 is closed, and the sample from multi-stream sampling system 20 flows into the MF chamber 41. When the

sample level reaches a predetermined level, the inlet valve 46 is closed and the stirrer 42 is actuated. Next, pH or ORP value is measured. The outlet valve 45 of a titration container is opened for a predetermined time interval (about 2 to 10 seconds) to add a predetermined volume of titration chemical to the MF chamber 41 for a predetermined period (around 20 points or 20 data collection). The pH or ORP value of solution is measured for each interval point. After the titration process is finished, the stirrer 42 is stopped and the outlet valve 43 is opened to empty the MF chamber 41. When the "end point" volume is consumed by the titration chemical, the control system 80 calculates the chemical consumption needed in the treatment process for the treatment tank 5. Now the MF chamber 41 is ready to perform titration for another treatment tank 5.

If the concentration of the waste chemical is very high such that it is unable to find the "end point" volume, a new titration process is carried out as earlier described except that the level of the sample into MF chamber 41 needs to reach a predetermined level lower than the previous one to reduce the volume of the sample in the MF chamber 41.

To start calibration, the outlet valve 45 of one standard chemical container and drain valve 43 are opened to let the standard chemical flush the MF chamber 41 for a predetermined time period and replace the solution left by a prior sample. Then the drain valve 43 is closed, and the standard chemical solution for calibration (for example, pH 4 buffer) from the standard chemical container 44 flows into the MF chamber 41. When the sample level reaches a predetermined level, the outlet valve 45 is closed, the stirrer 42 is actuated. The pH value is then measured. When the signal from the pH sensors reaches a stable value, the signal is recorded and stored in the control system 80. The pH sensor is calibrated in this standard solution. After completing calibration, the outlet valve 43 is opened to completely empty MF chamber 41. If the multiple point calibration is required, another outlet valve 45 is opened to MF chamber 41 and the processes can be repeated similarly as described.

To start washing, the outlet valve 71 of chemical cleaning liquid (for example, acid) container 70 and the inlet valve 47 of the MF chamber 41 are opened to let the chemical cleaning liquid flow into the MF chamber 41. When the level of the

cleaning liquid reaches a predetermined level, the outlet valve 71 and inlet valve 47 are closed. The stirrer 42 is actuated to drive the chemical solution to wash the MF chamber 41 and sensors inside for a predetermined time period (about one or two minutes). Then, the outlet valve 43 is opened to empty the MF chamber 41. In order to clean the residual chemical solution in the MF chamber 41 and sensors, the MF chamber 41 is rinsed with clean water after washing.

To start rinsing, the outlet valve 73 of the clean water container 72 and the inlet valve 47 are opened to let the clean water flow into the MF chamber 41. When the level of the clean water reaches a predetermined level, the outlet valve 73 and inlet valve 47 are closed. The stirrer 42 is actuated to drive the water to rinse the MF chamber 41 and sensors inside for a predetermined time period. Then, the outlet valve 43 is opened to empty the MF chamber 41. This can be repeated several times if necessary.

[2] ISE Chamber

ISE technology is useful for monitoring the anions during chemical analysis. As the measurement principles and procedures for various ISEs are similar, all ISEs are installed in an ISE chamber 50. In one embodiment, chloride (Cl^-), fluoride (F^-), cyanide (CN^-) and sulfide (S^{-2}) ISEs are selected and installed in the ISE chamber 50. More ISEs can be installed with minor modification. These four electrodes are also easily to be replaced by other commercial ISEs when necessary.

Six chemical containers 53 are coupled to the ISE chamber 50. Two chemical containers hold a chemical buffer to adjust the ion strength and measuring condition of the sample solution. The other four chemical containers hold a standard chemical solution for calibrating the ISEs. All chemical containers 53 are located about 40 centimetres higher than the ISE chamber 50. At the bottom of each container there is a solenoid valve 54. When the solenoid valve 54 is open, the chemical flows into the ISE chamber 50 from the container as a result of gravity.

Referring to Figures 6 and 7, four sensors 500 are installed near the bottom of the ISE chamber 50 to save the standard chemical during calibration. The sensors 500

include a chloride ISE, fluoride ISE, cyanide ISE and sulfide ISE. A motor 51 is installed in the top center to drive a small stirrer in the ISE chamber 50 to mix the solutions. A conductivity level switch 501 with four electrodes 502 is also installed to control the sample level at three setting points. All inlets coupled to the ISE chamber 50 are connected to a manifold such that only one pipe is coupled to the ISE chamber 50 directly. The ISE chamber 50 has an overflow pipe to prevent the ISE chamber 50 from abnormal level sensor conditions. At the bottom of the ISE chamber 50 there is a drain to completely empty according to the operating requirements. ISE chamber 50 has several different operation modes, including measurement, calibration and washing.

To start measurement, sample inlet valve 55 and drain valve 52 are opened to let the sample flush the ISE chamber 50 for a predetermined time period to replace the solution left by a prior sample. Then, the drain valve is closed, and the sample from multi-stream sampling system 20 flows into ISE chamber 50. When the sample level of the ISE chamber 50 reaches a predetermined level, the inlet valve 55 is closed. Then, the outlet valve 54 of one buffer solution container 53 is opened, and the buffer solution flows into the ISE chamber 50. When the sample level reaches a predetermined level, the outlet valve 54 is closed. The stirrer 51 is actuated to mix the solution in the ISE chamber 50 and measurement begins. When the control system 80 obtains stable signals from the ISE, the value of the concentration of anions is shown and recorded in the control system 80. If the signals from the ISE are not stable after the predetermined time period, the control system 80 stops the measurement and raises an alarm to remind the operator to check whether the electrodes or other instruments are faulty. The stirrer 51 is stopped, and the drain valve 52 is opened for a predetermined time period to completely empty the ISE chamber 50. Now it is ready to measure the next samples.

To start the calibration of an ISE (for example, chloride), the outlet valve 54 of one buffer solution container and the drain valve 52 are opened to let the buffer solution flush the ISE chamber 50 for a predetermined time period. Then, the drain valve 52 is closed, and the buffer solution flows into ISE chamber 50. When the sample level of the ISE chamber 50 reaches a predetermined level, the outlet valve 54 is closed. Then the outlet valve 54 of one standard solution container 53 is opened. The standard solution flows into the ISE chamber 50 for a predetermined time

period. The outlet valve 54 is closed and the stirrer 51 is actuated to mix the solution in the ISE chamber 50. Measurement can now begin. When the control system 80 obtains stable signals from the ISE, the value of the concentration of chloride of the standard solution is shown and recorded in the control system 80. The stirrer 51 is stopped, and the drain valve 52 is opened for a predetermined time period to completely empty the ISE chamber 50. If multiple point calibration is needed, ISE can be calibrated at a different concentration without changing the standard and buffer solution.

To start calibration of the same ISE (for example, chloride) at a different concentration, the same outlet valve 54 of the same standard solution container 53 is opened and the standard solution flows into the ISE chamber 50 for another predetermined time period which is longer than the previous calibration point. Outlet valve 54 is closed and the stirrer 51 is actuated to mix the solution and begin to measure. When the control system 80 obtains stable signals from the ISE, the value of the concentration of chloride of standard solution which is higher than the previous one is shown and recorded in the control system 80. The stirrer 51 is stopped, and the drain valve 52 is opened for a predetermined time period to completely empty the ISE chamber 50. The calibration result is obtained for chloride ion selective electrode in different concentrations.

The calibration of other ISEs in the ISE chamber 50 can follow the same procedures described earlier, except using a solenoid valve 54 related to a specific standard and buffer solution containers.

To start washing, outlet valve 71 of chemical cleaning liquid (for example, acid) container 70 and inlet valve 56 of the ISE chamber 50 are opened. The chemical cleaning liquid flows into the ISE chamber 50. When the level of the cleaning liquid reaches a predetermined level, the outlet valve 71 and inlet valve 56 are closed and the stirrer 51 is actuated to drive the chemical solution to wash the chamber and chemical sensors inside for a predetermined time period (about one or two minutes). Then, the outlet valve 52 is opened to empty ISE chamber 50. In order to clean the chemical left in the ISE chamber 50 and sensors, the ISE chamber 50 is rinsed with clean water after washing.

To start rinsing, the outlet valve 73 of the clean water container 72 and inlet valve 56 of the ISE chamber 50 are opened. The clean water flows into the ISE chamber 50. When the level of the clean water reaches a predetermined level, outlet valve 73 and inlet valve 56 are closed. The stirrer 51 is actuated to drive the water to rinse the ISE chamber 50 and chemical sensors inside for a predetermined time period. Then, outlet valve 52` is opened to empty the ISE chamber 50 to finish rinsing. Rinsing can be repeated several times as desired.

[3] HM Chamber

Anode stripping voltammetry (ASV) is a sensitivity method to measure the concentration of heavy metals. The ASV device is composed of a working glass carbon electrode, a countering electrode, and an Ag/AgCl reference electrode. In one embodiment, the three electrodes of ASV are installed in a HM chamber 60.

Six chemical containers 63 are coupled to the HM chamber 60. Two chemical containers hold a chemical buffer to adjust the ion strength and measuring condition of the sample solution. The other four chemical containers hold a standard chemical solution for calibrating the electrodes. All the containers 63 are located about 40 centimetres higher than the HM chamber 60. At the bottom of each container there is a solenoid valve. When the solenoid valve is open, the chemical flows into the HM chamber 60 from the container as a result of gravity.

Referring to Figures 8 and 9, three sensors 600 are installed near the bottom of the HM chamber 60 to save the standard chemical during calibration. The sensors 600 include a working electrode, counter electrode and reference electrode. A motor 61 is installed on the top center to drive a small stirrer in the HM chamber 60 to mix the solutions. A conductivity level switch 601 with four electrodes 602 is also installed in to control the sample level at three setting points. All inlets coupled to the HM chamber 60 are connected to a manifold such that only one pipe is coupled to the HM chamber 60 directly. The HM chamber 60 has an overflow pipe to prevent the HM chamber 60 from abnormal level sensor conditions. At the bottom of the HM chamber 60 there is a drain to completely empty the HM chamber 60 according to the operating requirements. The HM chamber 60 has several different operation modes, including measurement, calibration and wash.

To start the measurement, sample inlet valve 65 and drain valve 62 are opened to let the sample flush the HM chamber 60 for a predetermined time period to replace the solution left by a prior sample. Then, the drain valve is closed, and the sample from multi-stream sampling system 20 flows into the HM chamber 60. When the sample level reaches a predetermined level, the inlet valve 65 is closed. Then, the outlet valve 64 of one buffer solution container 63 is opened, and the buffer solution flows into the HM chamber 60. When the sample level reaches a predetermined level, the outlet valve 64 is closed. The stirrer 61 is actuated to mix the solution and the concentration of metallic ions of the sample is measured. When the control system 80 obtains stable signals from the three electrodes, the value of the concentration of metallic ions is shown and recorded in the control system 80. The stirrer 61 is stopped, and the drain valve 62 is opened for a predetermined time period to completely empty the HM chamber 60. Now it is ready to measure other samples.

To start calibration of the three electrodes for a metallic ion (for example, Zn^{2+}), outlet valve 64 of one buffer solution container 63 and drain valve 62 are opened to let the buffer solution flush the HM chamber 60 for a predetermined time period. Then, the drain valve 62 is closed and the buffer solution flows into the HM chamber 60. When the sample level reaches a predetermined level, the outlet valve 64 is closed. Then, the outlet valve 64 of one standard solution container 63 is opened and the standard solution flows into the HM chamber 60 for a predetermined time period. The outlet valve 64 is closed and the stirrer 61 is actuated to mix the solution in the HM chamber 60. The concentration of Zn^{2+} of the standard solution is then measured. When the control system 80 obtains stable signals from the three electrodes, the value of the concentration of Zn^{2+} of standard solution is shown and recorded in the control system 80. The stirrer 61 is stopped, and the drain valve 62 is opened for a predetermined time period to completely empty the HM chamber 60 to finish the calibration in one concentration of Zn^{2+}.

If multiple point calibration is required, the three electrodes can be calibrated at other concentration without changing the standard and buffer solution.

To start calibration of the same metallic ion (for example, Zn^{2+}) in another concentration, the same outlet valve 64 of the same standard solution container 63 is opened. The standard solution flows into the HM chamber 60 for another certain predetermined time period which is longer than the previous calibration point. The outlet valve 64 is closed and the stirrer 61 is actuated to mix the solution in the HM chamber 60. The concentration of Zn^{2+} is then measured. When the control system 80 obtains stable signals from the three electrodes, the value, which is higher than the previous one, is shown and recorded in the control system 80. The stirrer 61 is stopped, and the drain valve 62 is opened for a predetermined time period to completely empty the HM chamber 60 and finish the calibration of the three electrodes for different concentrations.

The calibration of other metallic ions in the HM chamber 60 may follow the same procedures described earlier, except using the solenoid valve related to a specific standard and buffer solution containers.

To start washing, outlet valve 71 of chemical cleaning liquid (for example, acid) container 70 and inlet valve 66 of the HM chamber 60 are opened to let the chemical cleaning liquid flow into the HM chamber 60. When the level of the cleaning liquid reaches a predetermined level, the outlet valve 71 and inlet valve 66 are closed. The stirrer 61 is actuated to drive the chemical solution to wash the HM chamber 60 and chemical sensors inside for a predetermined time period (about one or two minutes). Then, outlet valve 62 is opened to empty the HM chamber 60. In order to clean the chemical left in the HM chamber 60 and sensors, the HM chamber 60 is rinsed with clean water after washing.

To start rinsing, the outlet valve 73 of the clean water container 72 and inlet valve 66 of the HM chamber 60 are opened. The clean water flows into the HM chamber 60. When the level of the clean water reaches a predetermined level, the outlet valve 73 and inlet valve 66 are closed. The stirrer 61 is actuated to drive the water to rinse the HM chamber 60 and chemical sensors inside for a predetermined time period. Then, the outlet valve 62 is opened to empty the HM chamber 60 and finish rinsing. Rinsing can be repeated several times as desired.

Disposal Tank

Referring to Figures 10 and 11, the disposal tank 48 has a level switch, a diaphragm pump 49 and solenoid valves 28. A conductivity level switch 480 with three electrodes 481 is also installed to control the level of the disposal tank 48 between two setting points. All inlets coupled to the disposal tank 48 are connected to a manifold such that only one pipe is coupled to the disposal tank 48 directly. All chemical solutions used in the analysis chambers, including the MF chamber 41, ISE chamber 50 and HM chamber 60 are also drained to the disposal tank 48. When the level of the waste solution in the disposal tank 48 reaches a high predetermined level, the pump 49 is activated to pump the waste solution back to the treatment tanks 5. When the level of the waste solution in the disposal tank 48 is at a low predetermined level, the pump 49 is stopped. Solenoid valves 28 are interlocked and direct the waste solution back to a particular treatment tank 5.

Control System

The control system 80 is a Direct Digital Control System which includes a computer, local logic controllers and output devices. The logic controllers execute basic control functions. The computer manages the programmable logic computer (PLC) and is also used to configure and revise the control program.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the scope or spirit of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects illustrative and not restrictive.

WE CLAIM:

1. A testing system for continuous sampling and testing of effluent at a water treatment plant, the system comprising:

a sampling system to collect samples of the effluent;

a monitoring system connected to the sampling system, for measuring environmental parameters of the samples, the monitoring system comprising:

a first analysis chamber for measuring environmental parameters of at least two selected from the group consisting of: pH, oxidation reduction potential (ORP) value for state of reduction oxidation (Redox), conductivity value for total dissolved solids (TDS), dissolved oxygen (DO), turbidity (Tu) value for suspended solid (SS) and temperature (T);

a second analysis chamber for measuring the concentration of anions in the samples using a plurality of ion selective electrodes (ISEs); and

a third analysis chamber for measuring the concentration of heavy metals in the samples using anode stripping voltammetry (ASV); and

a control system to control the collection of samples by the sampling system, to control washing and rinsing of the analysis chambers, and to record the measurements obtained by the monitoring system.

2. The system according to claim 1, wherein the first, second and third analysis chambers perform measurements concurrently.

3. The system according to claim 1, wherein the samples of the effluent are collected from one or more treatment tanks of the water treatment plant.

4. The system according to claim 3, wherein the samples are collected sequentially.

5. The system according to claim 1, wherein each chamber further comprises a stirring device to mix the samples.

6. The system according to claim 1, wherein the first analysis chamber comprises a temperature probe, pH probe, ORP probe, conductivity probe, DO probe and turbidity probe, for measuring the environmental parameters.

7. The system according to claim 1, wherein the ion selective electrodes (ISEs) include a chloride ISE, fluoride ISE, cyanide ISE and a sulfide ISE.

8. The system according to claim 1, wherein the anode stripping voltammetry (ASV) is performed by an ASV device.

9. The system according to claim 8, wherein the ASV device comprises a working electrode, a counter electrode and a reference electrode.

10. The system according to claim 1, wherein the sampling system comprises:

a first sampling module to direct a first sample collected from a first treatment tank to the monitoring system via a sampling pipe; and

a second sampling module to rinse the sampling pipe with a second sample for a predetermined time period.

11. The system according to claim 10, wherein the sampling modules are connected by a switchover solenoid valve.

12. The system according to claim 10, wherein each sampling module comprises a diaphragm pump, a cross-flow membrane filter, a differential pressure transmitter, a manual control valve, an inlet solenoid valve and an outlet solenoid valve.

13. The system according to claim 12, wherein the pump is actuated to rinse the sampling pipe of the sampling modules for a predetermined time period.

14. The system according to claim 12, wherein the cross-flow membrane filter has a membrane to block particles larger than a predetermined membrane hole size.

15. The system according to claim 1, wherein the monitoring system further comprises a titration assembly, calibration assembly, washing assembly and a disposal assembly.

16. The system according to claim 15, wherein the washing assembly includes a container containing a chemical cleaning liquid.

17. The system according to claim 16, wherein the chemical cleaning liquid flows into any one of the chambers to wash the respective chamber.

18. The system according to claim 15, wherein the washing assembly includes a container containing clean water.

19. The system according to claim 18, wherein after washing, the clean water flows into any one of the chambers to rinse the respective chamber.

20. The system according to claim 19, wherein rinsing is performed more than once.

21. The system according to claim 15, wherein the disposal assembly includes a disposal tank to receive drainage of the samples, chemical cleaning liquid and clean water from the chambers.

22. The system according to claim 21, wherein the disposal tank comprises a level switch, diaphragm pump, and solenoid valves to direct the sample to a specific treatment tank.

23. The system according to claim 22, wherein the disposal tank comprises a conductivity level switch having three electrodes, to control the drainage volume in the disposal tank between a high level and a low level.

24. The system according to claim 23, wherein if the high level is reached, the pump is activated to return the drainage to the treatment tanks.

25. The system according to claim 23, wherein if the low level is reached, the pump is deactivated.

26. The system according to claim 15, wherein the titration assembly comprises a container to contain titration solution to simulate the treatment process in the testing system.