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A method of monitoring processes in an urban water cycle

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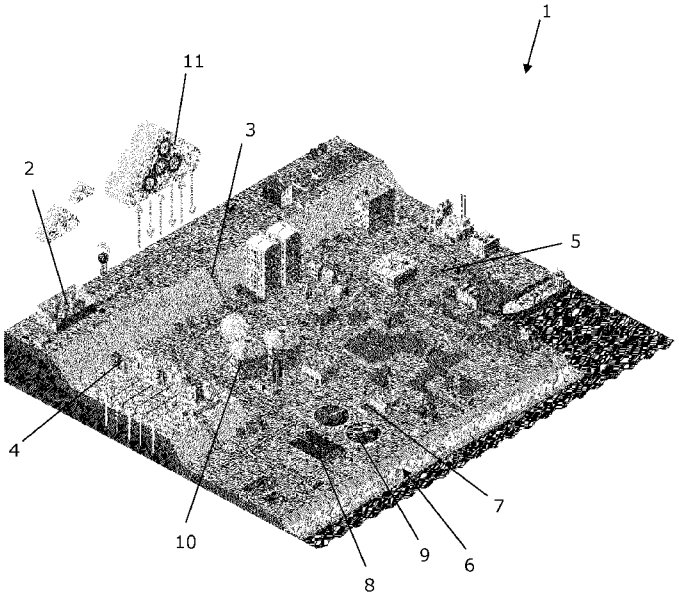

Fig. 1

(57) Abstract: The present disclosure provides method of monitoring a plurality of processes in an urban water cycle. The method comprises the steps of: defining an event having impact on a process activity of at least one process, defining a time-period, defining a first data set representing at least one expected process activity under impact of the event, the first data set comprising interrelated values of expected process activity and point in time in the time-period, determining a second data set representing actual process activity in the time-period, the actual process activity being the process activity under impact of the event, comparing the second data set representing actual process activity with the first data set representing expected process activity. Based thereon, a notification relating to the process activity for the at least one process is generated, if a deviation between the first data set and the second data set exceeds a predetermined threshold value in the time-period.

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A METHOD OF MONITORING PROCESSES IN AN URBAN WATER CYCLE

Field of the disclosure

The present disclosure relates to an improved method of monitoring processes in an urban water cycle.

Background of the disclosure

Typically, processes in an urban water cycle must be monitored frequently by an operator to ensure that the processes are running as intended. This is a demanding task which typically requires manual and time-consuming overview, analysis, and evaluation of several sensors and control signals.

Description of the disclosure

It is an object of embodiments of the disclosure to provide an improved method of monitoring processes in an urban water cycle.

It is a further object of embodiments of the disclosure to provide an improved method of monitoring processes in an urban water cycle which is less time-consuming.

According to a first aspect, the disclosure provides a method of monitoring a plurality of processes in an urban water cycle; the method comprising the steps of:

- defining an event having impact on a process activity of at least one process,

- defining a time-period,

- defining a first data set representing at least one expected process activity under impact of the event, the first data set comprising interrelated values of expected process activity and point in time in the time-period,

- determining a second data set representing actual process activity in the time-period, the actual process activity being the process activity under impact of the event,

- comparing the second data set representing actual process activity with the first data set representing expected process activity, and based thereon,

- generating a notification relating to the process activity for the at least one process, if a deviation between the first data set and the second data set exceeds a predetermined threshold value in the time-period.

In the context of the present disclosure the term 'urban water cycle' should be understood as general processes covering supply and sanitation services of water, including plants, pipes, and other elements. The processes may include processes relating to e.g. water catchment to obtain raw water, water treatment to treat water to make it suitable for drinking water, process water, and other types of water dependent on the subsequent use, water storage, including transportation of water to the storages e.g. by pumping, water distribution from storages to consumption sites, water collection after use, including transportation from consumption sites to wastewater treatment plants by sewage networks, and wastewater treatment which may make it possible to reuse water and to return it to the environment.

The processes in an urban water cycle may be monitored frequently by an operator to ensure that the processes are running as intended. Thus, monitoring as opposed to control is typically used to evaluate whether a process is running as expected. Measurements may be included in both monitoring and control, where measurement results often are used in a feedforward model to optimize the control in a control method. When monitoring, measurements may be used to evaluate processes over time in order to conclude if the overall dynamics are acceptable. Thus, implying that monitoring of e.g., equipment and bio/chemical processes is essential to secure that control can be applied to processes in an urban water cycle.

The method comprises a step of defining an event having impact on a process activity of at least one process in the urban water cycle. The event may be a user-initiated event or an event which is not initiated by a user, such as a rain event. The event may also be denoted a disturbance as it may change the process activity due to its impact hereon. A user-initiated event may as an example be a change of a setting within a plant within the urban water cycle; such as initiation or termination of pumping activity in a sewer system and/or in a wastewater treatment plant, initiation, increase, decrease, or termination of aeration activity, dosing of a substance e.g. in a wastewater treatment plant, etc.

When monitoring the processes, a time-period is defined. The duration of the time-period may in one embodiment be dependent on the defined event. In an alternative embodiment,

the time-period may be defined as a fixed time-period. In a further alternative, the time-period may be defined as a period comprising a fixed amount of data.

The event has an impact on a process activity of at least one process. It should be understood that an event may have an impact on a plurality of process activities of one or more processes. As an example, an event in the form of initiating aeration may impact different biomass activities, such as concentrations of ammonium, nitrate, phosphorus, etc., which may be lowered/increased, respectively, when aeration is initiated.

The method comprises a step of defining a first data set which represents at least one expected process activity under impact of the event. The data set comprises interrelated values of expected process activity and point in time in the time-period.

If the defined event as an example is initiation of aeration, the expected process activity may as an example be an increase of nitrate content. The first data set representing at least one expected process activity may thus comprise interrelated values of expected nitrate content and point in time, during the time-period. As initiation of aeration may further result in decrease of ammonium content, the first data set representing at least one expected process activity may further comprise interrelated values of expected ammonium content and point in time.

The first data set may as an example be determined based on previous measurements, on data analyses, e.g. by including statistical analysis, on modelling, etc. It should be understood that the first data set may be determined based on different input, such as a combination of previous measurements and data analysis.

The method further comprises a step of determining a second data set representing actual process activity in the time-period, where the actual process activity is process activity under impact of the event. As the event may be seen as a disturbance, as it may change the process activity due to its impact hereon, the actual process activity may also be denoted a disturbed process activity.

The actual process activity may as an example be measured by one or more sensors arranged in the urban water cycles. As an example, a sensor arranged in a process tank in a wastewater treatment plant may be used to measure nitrate content and/or ammonium content. As a further example, a sensor arranged in the sewer system may be used to measure flow. A sensor in a water treatment plant for treatment of raw water may be used to measure turbidity. The sensor(s) may be configured to send a signal representing the measured content/measured parameter to a control unit which may store the measured

content. The signal may further provide information of the point in time for the measurement, e.g., by providing a time stamp to the measurement. Alternatively, the point in time may be associated to the actual process activity by the control unit upon receipt of the signal. Thus, the second data set may as the first data set comprise interrelated values of process activity and point in time, where the process activity in the first data set is expected process activity and in the second data set is actual process activity.

As described above, the step of determining the second data set representing actual process activity may be based at least partly on measurements within the urban water cycle. As an example, data from the measurements may be used without any data processing. Alternatively, at least some of the measurement data may be processed and subsequently used when determining the second data set representing actual process activity.

Thus, the second data set may comprise directly determined data; i.e. values measured by one or more sensors or may comprise indirectly determined data; i.e. values being calculated/assessed or otherwise determined based on measured values.

At least some of the measurements may be online measurements, whereby the step of determining the second set representing actual process activity may be based on data continuously received to thereby provide a second data set which is based on real time values.

The first and second data sets may be stored in a computer system. It should further be understood that the first and/or second data set may further at least partly be determined by the computer system, e.g., based on measured values. The computer system could be constituted by one single computer with a data storage capacity and computer capability enabling storage of the first and second data sets and/or measured values. However, the computer system could also be distributed between two or more computer units. It could be distributed between different locations, and it could be set up for controlled access such that specific individuals may access individual parts of the computer system and individual parts of information contained therein.

It should further be understood that the method may be integrated in a computer system. The step of defining an event may be carried out by the computer, e.g., in the dependency of a predetermined time schedule. However, the step of defining the event may alternatively or additionally be carried out manually. As an example, an event in the form of increasing aeration of a tank may automatically be carried out based on a signal from the computer system, e.g., based on measurements and/or dependent on a predetermined time schedule.

In a computer implemented embodiment of the method, the step of defining the event may be manually carried out, as an operator may e.g., manually initiate increased aeration.

In a computer implemented embodiment of the method, the computer system may comprise a plurality of defined events which may be automatically initiated e.g., based on measurements and/or time schedule. Such events may as an example comprise start aeration, stop aeration, change aeration rate, start flow, stop flow, change flow rate, dose precipitation chemical, dose polymer, maturate filters, start by-pass flow, stop by-pass flow, change by-pass flow rate, etc.

It should further be understood that in a computer implemented embodiment of the method, the computer system that performs calculations and stores data may be located directly on-site, such as on a local server/computation unit or remotely located, such as in a cloud-based platform. In both cases, data from sensors and equipment may be handled using a Supervisory Control and Acquisition System (SCADA).

The method comprises a further step of comparing the second data set representing actual process activity with the first data set representing expected process activity. The comparison may be carried out by use of the control unit and/or a computer system in communication with the sensor(s) and/or the control unit. In one embodiment, the step of comparing may be automatically carried out by a computer system.

Based on the comparison of the first and second data set, a notification relating to the process activity for the at least one process is generated, if a deviation between the first data set and the second data set exceeds a predetermined threshold value in the time-period.

An operator may receive the notification and based on the received notification, the operator may start or increase surveillance of the defined event and/or the process activity on which the defined event has an impact. Thus, the method of monitoring a plurality of processes may be an evaluation of whether the processes behave as expected, and if not, it may further be investigated why the processes do not behave as expected.

As an example, the predetermined threshold value for the deviation may be in the range of +/- 5% in relation to the expected process activity. It should, however, be understood that the predetermined threshold value for the deviation may depend on the defined event, where the predetermined threshold value for the deviation may be in the range of +/- 1% in relation to a first expected process activity, in the range of +/- 5% in relation to a second expected process activity, in the range of +/- 10% in relation to a third expected process activity, and in the range of +/- 30% in relation to a fourth expected process activity. It

should further be understood that the predetermined threshold value may change, such as dependent on the time of the day and/or dependent on the time of the year. The deviation may be an average with-in the time-period, whereby a notification is generated if the average exceeds a predetermined threshold value. Alternatively, the deviation may be single value, whereby a notification is generated as soon as the deviation exceeds a predetermined threshold value. It should be understood that these steps may be combined, whereby a notification is generated if the average exceeds a predetermined first threshold value and a notification is generated as soon as the deviation exceeds a predetermined threshold value.

The urban water cycle may comprise at least one of a wastewater treatment plant for treatment of wastewater, a sewer system, a water treatment plant for treatment of raw water, and a water network for treated water. The water network and the sewer system may comprise a plurality of pipes, water pipes and sewer pipes, respectively, and a plurality of tanks, water tanks and sewer tanks, respectively. The wastewater treatment plant may comprise process tanks, clarification tanks, a grid chamber, etc. The treated water may as an example be drinking water and/or process water.

The process activity may be selected from a group consisting of: biomass activity, grit chamber activity, settler activity, clarifier activity, sewer activity, raw water activities, digester activity, dewatering activity, equalization activity, and other activities representing processes in the urban water cycle. As an example, the biomass activity may be one or more of a change over time of a content of e.g., NH4, NO3, PO4, DO, etc. The grit chamber activity may be one or more of flow, turbulence, temperature, etc. The settler activity may be one or more of SS concentration measured e.g., at the inlet, the outlet, and/or in return activated sludge, outlet turbidity, flow, return activated sludge flow, settleability, sludge blanket level, water temperature, etc. The clarifier activity may as an example be one or more of sludge blanket level, turbidity, etc. The sewer activity may be one or more of flow, level, etc. The raw water activities may as an example be coagulation, sedimentation, filtration, chlorination, etc.

The event may in one embodiment be selected from a group consisting of: start and/or stop and/or change of rate of any one of aeration, flow, return flow, recirculation flow, rain event, pumping, stirring, dosing of a substance, and backwash. It should be understood that other events capable of impacting processes of the urban water cycle may also be defined as an event.

It should further be understood that the event may be the start of one of the above examples, the termination/stop of one of the above, the change of one of the above. As an example, an event in the form of aeration may be an event in the form of starting the

aeration, in the form of terminating the aeration, and in the form of changing the rate of the aeration. In a further example, an event in the form of pumping may be an event in the form of starting pumping, in the form of terminating pumping, and in the form of changing the rate of pumping.

The event may as a further example include an on/off signal, a change of a setpoint of equipment.

The event may additionally derive from a previous event. As an example, an event in the form of increased nitrate recirculation flow may have the impact of increased content of recycled DO (Dissolved Oxygen) which may disturb/have an impact on the denitrification process. The first data set may represent an expected content of recycled DO over time and may thus comprise interrelated values of the content of recycled DO and point in time in the defined time-period. A notification may thus be generated if the deviation between the first data set (expected content of DO) and the second data set (measured content of DO) exceeds a predetermined threshold value.

The increased content of DO may, however, have an impact on the denitrification process, and an additional notification may thus be generated if the deviation between a first data set representing expected content of nitrate and a second data set representing measured content of nitrate exceeds a predetermined threshold value.

The event may be controllable by a control action, and the method may comprise a step of activating the control action. The control action may as an example be start of aeration, termination of stirring, change of flow rate, etc. The step of activating the control action may be a manual action or an automatic action, e.g., in dependence of a time schedule or as determined automatically by existing control. In one embodiment, some control actions may be manually activated, whereas other control actions may be automatically activated.

In other words, the method may further comprise a step of initiating the event. As described above, the event may be a user-initiated event, an event which is not initiated by a user, such as a rain event, or an event derived from another event, such as change of a content of a substance over time initiated by the change of another substance and/or parameter.

The step of determining the second data set may be carried out in real time; i.e. the second data set may be determined based on measurements transferred, e.g. to a control unit, without any substantial delay. Thus, the second data set may be determined by automatically using data from online sensors, e.g., by the use of an algorithm without manual interference.

The step of comparing the second data set with the first data set may comprise a step of defining a delayed response time for the event, where defining of the delayed response time may be carried out by modelling and/or estimation, e.g., based on historical values.

By the term 'delayed response time' should be understood that the actual process activity may begin or may become observable after a certain time-period after the event has started, where this certain time-period is the 'delayed response time'. As an example, if the event is in the form of start aeration and the process activity is Dissolved Oxygen (DO), a change of the content of Dissolved Oxygen will only be measurable after a certain time-period; i.e. a delayed response time may be determined as part for the step of comparing the first data set and the second data set. This may be achieved by comparing the expected process activity with actual process activity at different times, i.e., by shifting the time series of one of the first and second data set to better match the other one of the first and second data set.

The first data set may comprise historical data for the process activity, where the historical data may comprise interrelated values of measured process activity and point in time. The historical data may be divided into a number of time segments, each comprising historical data.

The time segments may each be of the same length, such as each time segment being 10 minutes, being 1 hour, being 2 hours, being 4 hours, being 8 hours, being 12 hours, or of another length. It should however be understood that at least some of the time segments may be of different length, such as one or more time segments of 10 minutes, one or more time segments of 1 hour, or of another length.

In one embodiment, the step of defining the first data set may be based at least partly on historical data. The first data set may further comprise a ranking parameter which may rank later time segments higher than earlier time segments. Thus, when at least partly basing the first data set on historical data, the latest; i.e. the newest data may be weighted higher than earlier; i.e. older data. Thus, the method may comprise a step of adding the ranking parameter as a weight factor to the data in each time segment. The ranking parameter may as an example depend on the type of process activity, the type of event defined, the time of the year, etc. Additionally, or alternatively, later time segments may be shorter than earlier time segments. By providing later time segments being shorter than older time segments, the historical data may comprise more late data than early data.

The method may further comprise a step of preparing a mathematical model providing simulation data as a function of process activity measured in the urban water cycle by at least one sensor. The step of defining the first data set may comprise a step of defining

interrelated values of simulation data and point in time. In one embodiment, the first data set may be based on historical data and simulated data. Thus, the first data set representing expected process activity may be based on previously measured activity, estimated activity, calculated activity, e.g. by use of previously measured data, simulated activity, or data otherwise provided.

The mathematical models may be formulated such that 1) the models may be able to run fast enough for real-time applications, 2) information from e.g., time series of flow, rain gauges, and other factors from forecast information and/or historical data can be utilized for operational purposes, and 3) the same model may be used for both forecasting, control, simulation, risk analysis, optimization, and scenario generation.

The mathematical modelling may comprise the use of methodologies for stochastic dynamical modelling using grey-box technologies which may also be called semi-physical, transparent, mechanistic, or surrogate modelling. Consequently, it may be possible to bridge the gap between physical and statistical modelling, as combined information from physics and information from data may be used by the model. The grey-box technologies may be based on real-time data; i.e. data which is measured and subsequently transferred to the mathematical model for modelling without any substantial delay.

Alternatively, mathematical models may be based on deterministic modelling, may employ neural networks, and/or machine learning. It should be understood that other types of modelling may also be applied.

The step of determining the first data set representing at least one expected process activity may comprise a step of mathematically modelling an impact of the event on the process activity. Mathematical modelling as describe above may be applied.

As at least some events may be controllable by a control action, the method may further comprise a step of deactivating the control action based on the generated notification. The deactivation step may be a step of pausing the event or a step of completely stopping the event, by deactivating the control action.

As described above, the defined event may as an example be initiation of aeration, whereby the expected process activity may be an increase of nitrate content. The first data set representing at least one expected process activity may thus comprise interrelated values of expected nitrate content and point in time, and the second data set representing actual process activity in the time-period may comprise interrelated values of measured nitrate content and point in time. Based on the comparison of the first and second data set, a

notification relating to the process activity for the at least one process is generated, if a deviation between the first data set and the second data set exceeds a predetermined threshold value. In this example, the notification may be used to provide a signal to an operator, that the aeration should be terminated.

As described above, a notification is generated if the deviation between the first data set representing expected nitrate content over time and the second data set representing measured nitrate content over time exceeds a predetermined threshold value. An operator may, based on the notification, check different elements which may have an influence on the measured value, such as a sensor measuring the nitrate content, a control unit which is used to control aeration, an air blower, a stirring unit, etc. Thus, the operator may use the notification as a starting point for manual review of the elements. Alternatively, the notification may initiate an automatic review of at least some of the elements relating to the event and/or the process activity.

The method may in one embodiment comprise a further a step of initiating a second event based on the generated notification.

Examples

Example 1: Process checker for alternating activated sludge nitrogen removing process

Event: Switching the mode (i.e. on/off) on the aeration equipment in the process tank(s)

Process activity: Changes in ammonium and nitrate concentrations in the process tank(s)

Description: When aeration is turned on, the observed ammonium concentration is expected to decrease, possibly after a reaction time. Likewise, the observed nitrate concentrations are expected to increase.

Example 2: Return activated sludge

Event: Changing the flow in the return activated sludge pump

Process activity: Changes in sludge blanket height

Description: When the flow is increased in the return activated sludge pump, the sludge blanket height is expected to decrease. Likewise, the sludge blanket height is expected to

increase if flow in return activated sludge pump is decreased. This might happen after a reaction time in the system.

Example 3: Biological phosphorus removal

Event: Switching the mode (i.e. on/off) on the aeration equipment

Process activity: Changes in phosphorus concentration

Description: Similar to example 1, biological phosphorus removal is expected to change depending on changes in the mode of the aeration equipment. Aeration being turned "on" is expected to result in decreasing phosphorus concentration. Likewise, aeration turned "off" is expected to result in increasing phosphorus concentrations. This might happen after a reaction time in the system.

Example 4: Precipitation chemical for phosphorus removal

Event: Dosing precipitation chemical

Process activity: Changes in phosphorus concentration

Description: When precipitation chemical is dosed to the system, phosphorus concentration is expected to decrease. Likewise, when the dosage of precipitation chemical is stopped, concentrations are expected to increase. This might happen after a reaction time in the system.

Example 5: Carbon dosing

Event: Changing carbon dosing rate

Process activity: Changes in nitrate concentrations

Description: When carbon is dosed to the system, the nitrate removal rates are expected to increase, i.e. nitrate concentration is expected to decrease faster. Likewise, when carbon dosage is stopped or decreased, nitrate removal rates are expected to decrease. This might happen after a reaction time in the system.

Example 6: Pumping station pump flow

Event: Changing the pumping flow in a pumping station

Process activity: Observed changes in filling degree in downstream basin/pipes and/or observed changes in downstream flow measurements

Description: When pumping is increased in a pump in a sewer system catchment, the downstream filling degree of certain basins and/or flow in certain pipes is expected to increase. Likewise, when pumping is decreased these are expected to decrease. This might happen after a reaction time in the system.

Example 7: Wet weather influence checker

Event: Rain events causing peak flows that are distinguishable from dry weather flow

Process activity: Observed changes in nutrient concentrations at WWTP and/or turbidity

Description: When distinct flows caused by sufficiently large rain events are detected either upstream in the sewer system or at the inflow to the wastewater treatment plant, an increase in ammonium concentration and/or turbidity is expected. This might happen after a reaction time in the system.

Example 8: Recirculation pumping checker

Event: Changing the recirculation pump setpoint

Process activity: Observed changes in nitrate concentrations

Description: When recirculation pumping is increased, upstream tanks that receive the wastewater from further downstream is expected to experience increasing nitrate concentration and decreasing ammonium concentration. This might happen after a reaction time in the system.

Example 9: Digester gas production

Event: Changing the feeding flow and/or total solids (TS) concentration

Process activity: Observed changes in gas production

Description: When the feeding flow is increased and/or TS concentration is increased to the digester, gas production is expected to increase (assuming temperature etc. are kept constant). Likewise, when the feeding flow is decreased and/or TS concentration is decreased to the digester, gas production is expected to decrease. This might happen after a reaction time in the system.

Example 10: Dewatering

Event: Changing the polymer dosing

Process activity: Changes in TS concentration dewatered sludge

Description: When the polymer dosing is increased, the TS concentration in the dewatered sludge is expected to increase. Likewise, when polymer dosing is decreased, the TS concentration in dewatered sludge is expected to decrease. This might happen after a reaction time in the system.

Example 11: Drinking Water, Filter operation

Event: Maturation (ripening) of filters following backwash

Process activity: Changes in outlet turbidity

Description: Following backwash, the filter typically exhibits a period with reduced particle removal (the ripening/maturation period). During this period, the turbidity in the outlet of the filter is expected to decrease until optimal performance is achieved.

Brief description of the drawings

Embodiments of the disclosure will now be further described with reference to the drawings, in which:

Fig. 1 illustrates an urban water cycle;

Fig. 2 illustrates a flow diagram for the method, and

Fig. 3 illustrates an embodiment of a flow diagram for the method.

Detailed description of the drawings

It should be understood that the detailed description and specific examples, while indicating embodiments of the disclosure, are given by way of illustration only, since various changes and modifications within the scope of the disclosure will become apparent to those skilled in the art from this detailed description.

Fig. 1 illustrates an urban water cycle 1, in which general processes covering supply and sanitation services of water takes place. The processes may include processes relating to e.g. water catchment to obtain raw water, water treatment to treat water to make it suitable for drinking water, process water, and other types of water dependent on the subsequent use, water storage, including transportation of water to the storages e.g. by pumping, water distribution from storages to consumption sites, water collection after use, including transportation from consumption sites to wastewater treatment plants by sewage networks, and wastewater treatment which may make it possible to reuse water and to return it to the environment.

The illustrated urban water cycle 1 comprises a raw water treatment plant 2 for treatment of raw water, and a drinking water network in the form of water pipes 3 and water towers 4. It should be understood that the drinking water network also comprises pumps, valves, and other elements to transport drinking water from the raw water treatment plant 2 to the user. In the schematic illustration of the urban water cycle 1 these elements are omitted. Likewise, are the different plant elements of the raw water treatment plant 2 omitted.

The urban water cycle 1 further comprises a sewer system 5. The sewer system 5 comprises sewer pipes, manholes, basins, weirs, etc.

Furthermore, the urban water cycle 1 comprises a wastewater treatment plan 6 which comprises a pre-treatment section 7 with grit chamber, grease trap, etc, a biological treatment section 8, and clarifiers 9. It should be understood that the wastewater treatment plant 6 also comprises pumps, valves, and other elements.

The urban water cycle 1 further comprises anaerobic digesters 10. Rain events and evaporation are illustrated by the cloud 11 with associated arrows.

It should be understood that the above-described elements are for illustration of the urban water cycle 1, and that an urban water cycle according to the disclosure may comprises other elements too.

Fig. 2 illustrates a flow diagram 100 of the method. The method is initiated in step 101 in which an event having impact on a process activity of at least one process is defined. Furthermore, a time-period is defined. The duration of the time-period defined may depend on the events defines.

In step 102, a first data set representing at least one expected process activity is defined. It should be understood, that a plurality of first data sets may be defined in step 102, where each of the first data sets represents at least one expected process activity.

In step 103, a second data set representing actual process activity in the time-period is determined, where the actual process activity is process activity under impact of the event defined in step 101.

In step 104, the second data set representing actual process activity is compared with the first data set representing expected process activity.

If the deviation between the first data set and the second data set exceeds a predetermined threshold value, a notification relating to the process activity for the at least one process is generated in step 105a.

If the deviation between the first data set and the second data set is below a predetermined threshold value, no notification relating to the process activity for the at least one process is generated in step 105b.

Fig. 3 illustrates an embodiment of a flow diagram 100 for the method. The method is initiated in step 101 in which an event having impact on a process activity of at least one process is defined. In the illustrated embodiment, the defined event is aeration of a process tank in an activated sludge plant. The defined event may be manually initiated/controlled by a control action, e.g. by changing a setpoint for Dissolved Oxygen (DO). It should however be understood that the defined event may alternatively be automatically initiated, e.g., by changing a setpoint for Dissolved Oxygen (DO) in response to measurements and/or in response to an earlier notification and/or in response to a time schedule, etc.

In step 102, two first data sets representing at least one expected process activity is defined, where one of the first data sets represents expected nitrate concentration over time, and where the other one of the first data sets represents expected ammonium concentration over time. It should be understood that in an alternative embodiment, a single first data set representing both expected nitrate concentration and expected ammonium concentration may be applied.

In step 103, two second data sets representing actual process activity in the time-period is determined, where the actual process activity is process activity under impact of the event define in step 101. In this embodiment, the second data sets comprise measured values of nitrate concentration and ammonium concentration, respectively. As described above, a single second data set representing both measured nitrate concentration and measured ammonium concentration may be applied.

In step 104, the second data sets representing actual process activity is compared with the first data sets representing expected process activity. Thus, the expected nitrated concentration over time is compared with the measured nitrate concentrate over time, whereas the expected ammonium concentration over time is compared with the measured ammonium concentrate over time.

If the deviation between the first data set and the second data set exceeds a predetermined threshold value, a notification relating to the process activity for the at least one process is generated in step 105a. If the deviation between the first data set and the second data set is below a predetermined threshold value, no notification relating to the process activity for the at least one process is generated in step 105b. It should be understood that a notification is generated if the deviation for one of the data sets exceeds a predetermined threshold value. Thus, a notification based on nitrate may be generated, if the deviation relating to nitrate exceeds the threshold value for nitrate, whereas no notification may be generated, if the deviation relation to ammonium does not exceed the threshold value for ammonium. It should further be understood that two notifications may be generated, if both the deviation relating to nitrate and the deviation relating to ammonium exceed the respective threshold values.

An operator may, based on the notification, check different elements which may have an influence on the measured value, such as a sensor measuring the nitrate content and/or the ammonium content depending on whether the notification relates to nitrate and/or ammonium, a control unit which is used to control aeration, an air blower, a stirring unit, etc. Thus, the operator may use the notification as a starting point for manual review of the elements. Alternatively, the notification may initiate an automatic review of at least some of the relating to the event and/or the process activity.

CLAIMS

1. A method of monitoring a plurality of processes in an urban water cycle; the method comprising the steps of:

- defining an event having impact on a process activity of at least one process,

- defining a time-period,

- defining a first data set representing at least one expected process activity under impact of the event, the first data set comprising interrelated values of expected process activity and point in time in the time-period,

- determining a second data set representing actual process activity in the time-period, the actual process activity being the process activity under impact of the event,

- comparing the second data set representing actual process activity with the first data set representing expected process activity, and based thereon,

- generating a notification relating to the process activity for the at least one process, if a deviation between the first data set and the second data set exceeds a predetermined threshold value in the time-period.

2. A method of monitoring according to claim 1, wherein the urban water cycle comprises at least one of a wastewater treatment plant for treatment of wastewater, a sewer system, a water treatment plant for treatment of raw water, and a water network for treated water.

3. A method of monitoring according to claim 1 or 2, wherein the process activity is selected from a group consisting of: biomass activity, such as change over time of a content of e.g. NH4, NO3, PO4, DO,, grit chamber activity, such as flow, turbulence, temperature, sewer activity, such as at least one of filling degree of basin(s), filling degree of pipes, and change of flow , raw water activities, such as coagulation, sedimentation, filtration, chlorination, digester activity, such as change of gas production, dewatering activity, such as change of TS concentration, and equalization activity.

4. A method of monitoring according to any of the preceding claims, wherein the event is selected from a group consisting of: start and/or stop and/or change of rate of any one of

aeration, flow, return flow, recirculation flow, rain event, pumping, stirring, dosing of a substance, and backwash.

5. A method of monitoring according to any of the preceding claims, wherein the event is controllable by a control action, and wherein the method further comprising a step of activating the control action.

6. A method of monitoring according to any of the preceding claims, wherein the step of determining the second data set is carried out in real time.

7. A method of monitoring according to any of the preceding claims, wherein the step of comparing the second data set with the first data set comprises a step of defining a delayed response time for the event.

8. A method of monitoring according to any of the preceding claims, wherein in the first data set comprises historical data for the process activity, wherein the historical data comprises interrelated values of measured process activity and point in time.

9. A method of monitoring according to claim 8, wherein the step of defining the first data set is based at least partly on historical data, wherein the first data set further comprises a ranking parameter ranking later time segments higher than earlier time segments.

10. A method of monitoring according to any of the preceding claims, further comprising a step of preparing a mathematical model providing simulation data as a function of process activity measured in the urban water cycle by at least one sensor, wherein the step of defining the first data set comprises a step of defining interrelated values of simulation data and point in time.

11. A method of monitoring according to claim 9, wherein the first data set is based on historical data and simulated data.

12. A method of monitoring according to any of the preceding claims, wherein the step of determining the second data set representing actual process activity is based at least partly on measurements within the urban water cycle.

13. A method of monitoring according to claim 12, wherein at least some of the measurements are online measurements.

14. A method of monitoring according to any of the claims 5-13, further comprising a step of deactivating the control action based on the generated notification.

15. A method of monitoring according to any of the preceding claims, further comprising a step of activating a second event based on the generated notification.

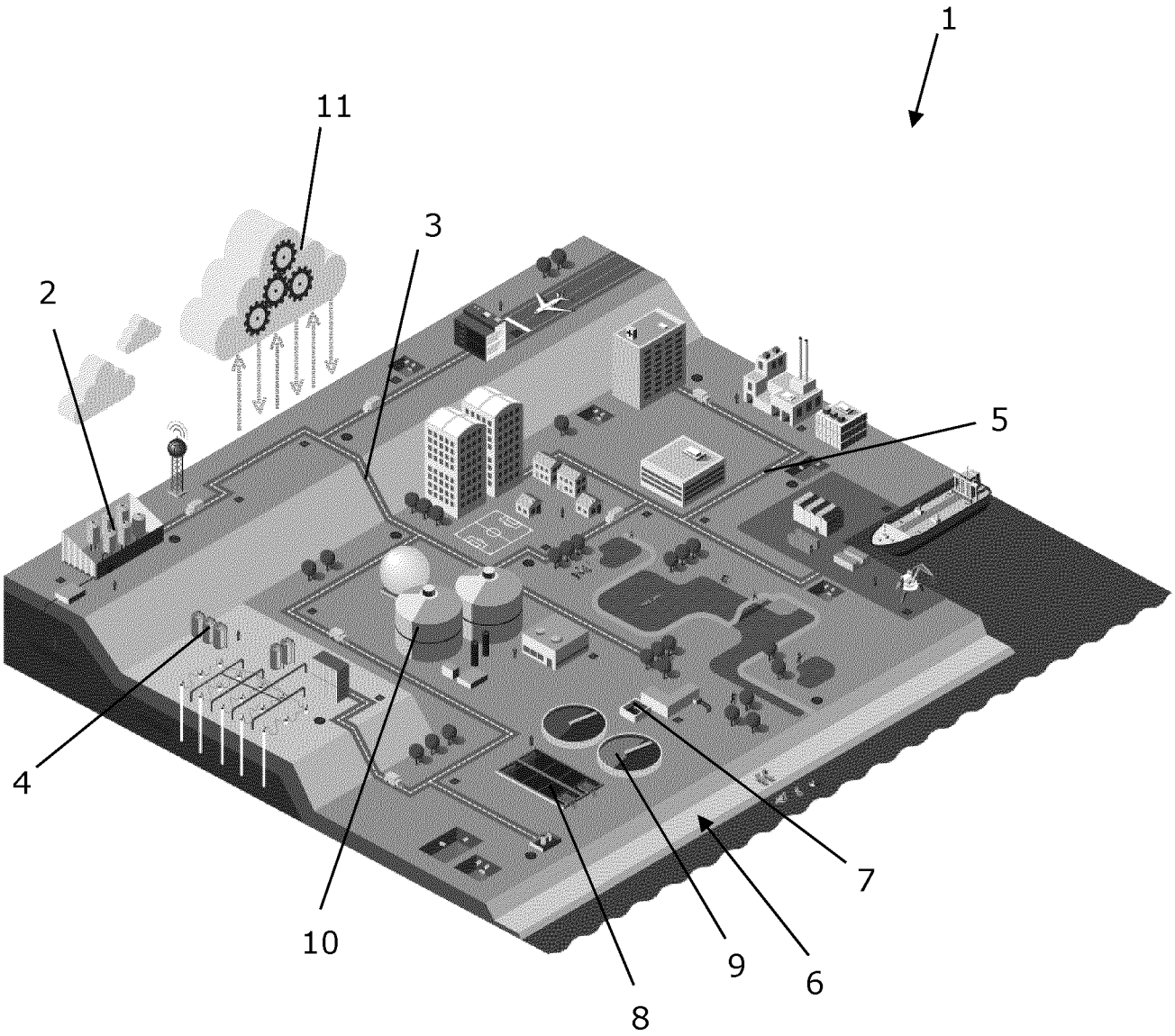

Fig. 1

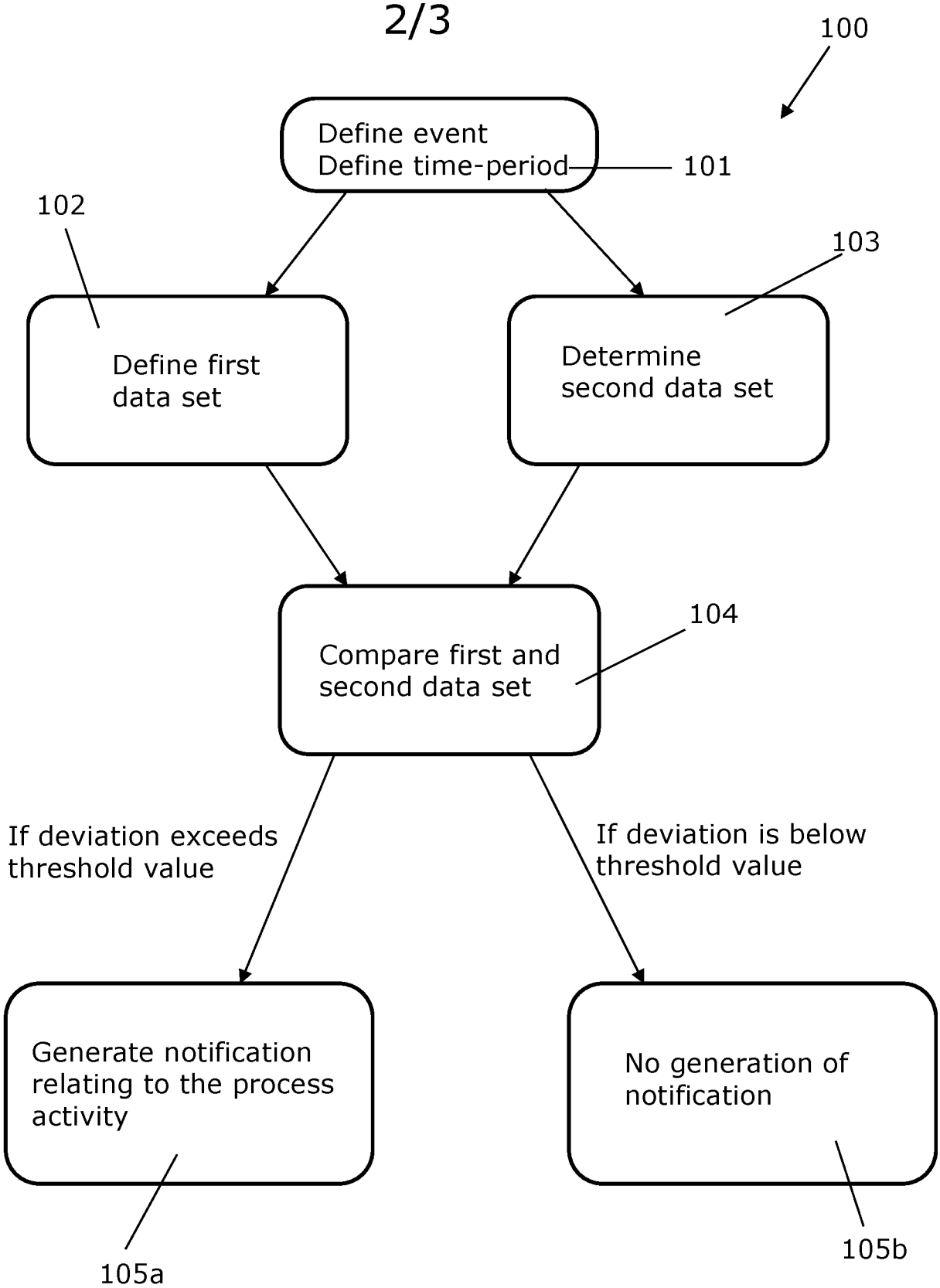
100
Define event
Define time-period
101
102
103
Define first data set
Determine second data set
104
Compare first and second data set
If deviation exceeds threshold value
If deviation is below threshold value
Generate notification relating to the process activity
No generation of notification
105a
105b

Fig. 2

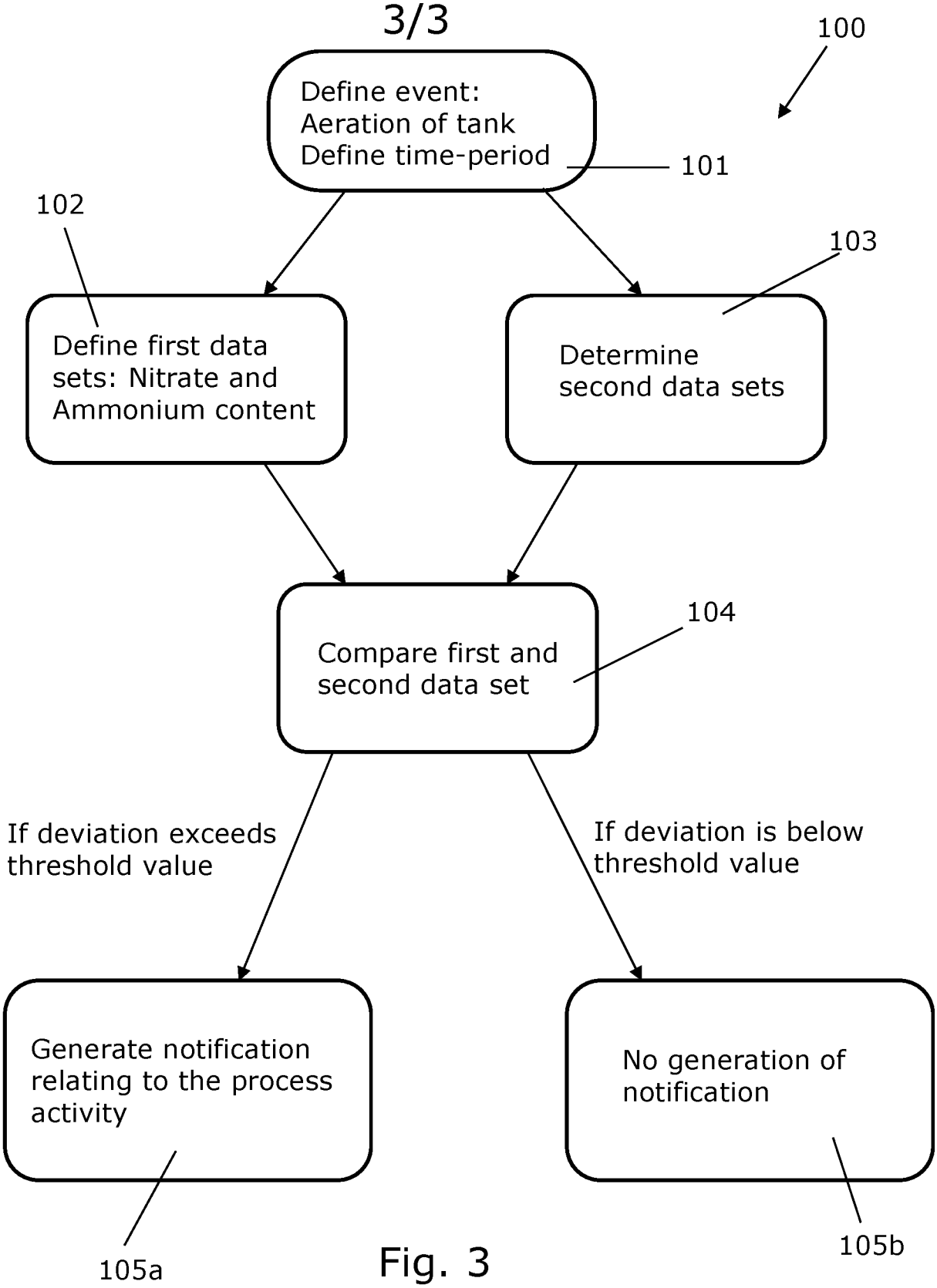
100
Define event:
Aeration of tank
Define time-period
101
102
103
Define first data sets: Nitrate and Ammonium content
Determine second data sets
104
Compare first and second data set
If deviation exceeds threshold value
If deviation is below threshold value
Generate notification relating to the process activity
No generation of notification
105a
105b

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/087472

A. CLASSIFICATION OF SUBJECT MATTER

INV. G05B23/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AU 2020 240 738 A1 (SUMITOMO HEAVY INDUSTRIES [JP]) 14 October 2021 (2021-10-14) paragraphs [0017], [0023], [0040] - [0042]; figures 1-4 paragraph [0017] paragraph [0023] paragraph [0040] - paragraph [0042]	1-4,12

X	KR 101 985 343 B1 (KOREA CONVERGNENCE IT CO LTD [KR]) 4 June 2019 (2019-06-04) paragraphs [0001], [0002], [0005], [0008], [0016], [0034] - [0036]; figures 1-4	1-4,12

	-/--	

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 2023	07/06/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Fulcheri, Alessandro

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/087472

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021/356943 A1 (TAGUCHI YASUNORI [JP] ET AL) 18 November 2021 (2021-11-18) paragraph [0003]; figures 1,13 paragraph [0036] paragraph [0037] paragraph [0039] paragraph [0040] - paragraph [0041] paragraph [0048] - paragraph [0050] paragraph [0051] - paragraph [0052] paragraph [0123] paragraph [0130] paragraph [0131] - paragraph [0137] paragraph [0181] - paragraph [0184] -----	1-6,8, 10-13

3

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

International application No.
PCT/EP2022/087472

INTERNATIONAL SEARCH REPORT

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

1-13

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8, 10-13

   A method of monitoring a plurality of processes in an urban water cycle.
   Comprises comparing a second data set with the first data set by defining a delayed response time for a time event.

   ---

2. claim: 9

   A method of monitoring a plurality of processes in an urban water cycle.
   Wherein a step of defining the first data set is based at least partly on historical data, wherein a first data set further comprises a ranking parameter ranking later time segments higher than earlier time segments.

   ---

3. claims: 14, 15

   A method of monitoring a plurality of processes in an urban water cycle.
   Comprises a step of deactivating the control action based on the generated notification.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2022/087472

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
AU 2020240738 A1	14-10-2021	AU 2020240738 A1	14-10-2021
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		EP 3940491 A1	19-01-2022
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KR 101985343 B1	04-06-2019	NONE	
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