Australian Government

IP Australia

CERTIFICATE OF GRANT

INNOVATION PATENT

2017101571

The Commissioner of Patents has granted the above patent on 22 November 2017, and certifies that the following are the particulars of this patent appearing in the Register of Patents:

Name and Address of Patentee(s):

EXPERT 365 PTY LTD

2/31 Ipswich Rd., Woolloongabba Woolloongabba QLD 4102 Australia

Name of Actual Inventor(s):

Karri, Vishy and Karri, Roshan

Title of Invention:

A METHOD AND APPARATUS FOR ON-LINE DETECTION OF COLIFORMS AND ESCHERICHIA COLI IN WATER

Term of Patent:

Eight years from 7 November 2017

NOTE: This Innovation Patent cannot be enforced unless and until it has been examined by the Commissioner of Patents and a Certificate of Examination has been issued. See sections 120(1A) and 129A of the Patents Act 1990, set out on the reverse of this document.

COMMONWEALTH OF AUSTRALIA
AUSTRALIA
PATENT OFFICE

Dated this 22nd day of November 2017

Commissioner of Patents

PATENTS ACT 1990

Extracts from the Patents Act, 1990

Sect 120(1A) Infringement proceedings in respect of an innovation patent cannot be started unless the patent has been certified.

Sec 128 **Application for relief from unjustified threats**

(1) Where a person, by means of circulars, advertisements or otherwise, threatens a person with infringement proceedings or other similar proceedings a person aggrieved may apply to a prescribed court, or to another court having jurisdiction to hear and determine the application, for:

(a) a declaration that the threats are unjustifiable; and

(b) an injunction against the continuance of the threats; and

(c) the recovery of any damages sustained by the applicant as a result of the threats.

(2) Subsection (1) applies whether or not the person who made the threats is entitled to, or interested in, the patent or a patent application.

Sec 129A **Threats related to an innovation patent application or innovation patent and courts power to grant relief.**

Certain threats of infringement proceedings are always unjustifiable.

(1) If:

(a) a person:

(i) has applied for an innovation patent, but the application has not been determined; or

(ii) has an innovation patent that has not been certified; and

(b) the person, by means of circulars, advertisements or otherwise, threatens a person with infringement proceedings or other similar proceedings in respect of the patent applied for, or the patent, as the case may be;

then, for the purposes of an application for relief under section 128 by the person threatened, the threats are unjustifiable.

Courts power to grant relief in respect of threats made by the applicant for an innovation patent or the patentee of an uncertified innovation patent

(2) If an application under section 128 for relief relates to threats made in respect of an innovation patent that has not been certified or an application for an innovation patent, the court may grant the application the relief applied for.

Courts power to grant relief in respect of threats made by the patentee of certified innovation patent

(3) If an application under section 128 for relief relates to threats made in respect of a certified innovation patent, the court may grant the applicant the relief applied for unless the respondent satisfies the court that the acts about which the threats were made infringed, or would infringe, a claim that is not shown by the applicant to be invalid.

Schedule 1 **Dictionary**

certified, in respect of an innovation patent other than in section 19, means a certificate of examination issued by the Commissioner under paragraph 101E(e) in respect of the patent

A METHOD AND APPARATUS FOR ON-LINE DETECTION OF COLIFORMS AND ESCHERICHIA COLI IN WATER

Background of the Invention

[0001]

This invention relates to a method and apparatus for use in on-line detection of coliform bacteria and E-Coli in water.

Description of the Prior Art

[0002]

The coliform group has been used extensively as an indicator of water quality and forms a mandatory requirement for compliance in establishing water quality. The prior art highlighted here shows methods currently in use for monitoring of coliforms in water. Current methods used in detection of coliforms and Escherichia coli typically rely on coarse assumptions regarding the incubation duration, antagonistic organism interference, poor detection of slow growing rate and viable but non-culturable organism interference (VNBC). Most prevalent method to quantify coliforms is a member filter technique for water. This method is enhanced using enzymatic activity where beta-D galactosidase and beta-D glucuronidase are widely used for the detection and enumeration of total coliforms and Escherichia coli (E-Coli), respectively. Several chromogenic and fluorogenic substrates exist for the specific detection of these enzymatic activities, and various commercial tests based on these substrates are available. Numerous comparisons have shown these tests may be a suitable alternative to the classical membrane filter techniques. These tests can be expensive and often prohibitive with large incubation times, even though reduced, remains too long for same-day results. Efforts to decrease these lengthy incubation times, via solid phase cytometry, have been employed with a low detection threshold. The problem of identifying the colony numbers is exasperated when natural colony increase associated with changes in temperature and time.

[0003]

Detection of coliforms by molecular methods is also evident in the literature, as these methods allow for very specific and rapid detection without the requirement for a cultivation step. The popular molecular-based methods are; immunological method, polymerase chain reaction

(PCR) method and in-situ hybridization (ISH) method. In the immunological approach, various antibodies against coliform bacteria have been produced, but the application of this technique often showed low antibody specificity. PCR can be used to detect coliform bacteria by means of signal amplification: DNA sequence coding for the lacZ gene (beta-galactosidase gene) and the uidA gene (beta-D glucuronidase gene) has been used to detect total coliforms and E. coli, respectively. However, quantification with PCR is still lacking in precision and necessitates extensive laboratory work. The ISH technique involves the use of oligonucleotide probes to detect complementary sequences inside specific cells. Oligonucleotide probes designed specifically for regions of the 16S RNA molecules of Enterobacteriaceae can be used for microbiological quality control of drinking water samples. ISH is seen as a viable alternative to the conventional culture methods for the detection of coliforms in drinking water, as it provides quantitative data in a fairly short period of time (6 to 8 h). However, it still requires extensive research for reliable quantitative estimation. This current state of the art shows that even though many innovative bacterial detection methods have been developed, few have the potential for becoming a standardized method for the detection of coliforms in drinking water samples. The longer waiting times, accuracy, antagonistic organism interference and cost associated are still pressing issues in identifying Coliforms and E-Coli in water.

[0004]

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that the prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

Summary of the Present Invention

[0005]

In one broad form an aspect of the present invention seeks to provide a method and apparatus for use in performing on-line detection of Coliforms and E-Coli in water, the method being performed using one or more electronic processing devices, the method including: receiving, from at least one electrical conductivity (EC) sensor located in water , at least one nitrate and nitrite measurements of the water, at least one sensor measuring ammonium content in water, at least two sensors measuring turbidity and colour; estimating most probable number of Coliforms and E-Coli per 100 millilitres of water as two separate calculations, based on the sensors output along with temperature and solar irradiance from meteorological data source, meteorological data for a geographical region corresponding to the water location and time period; determining indicative of total nitrogen content at least one solar irradiance value for the prior time period based on at least some of the meteorological data; and calculating most probable number of coliforms and E-Coli per 100 millilitres of water.

[0006]

In one embodiment, the method includes: determining total nitrogen from nitrite, nitrate and ammonium values using different techniques; determining a maximum nitrogen value from the plurality of calculated nitrogen values; determining electrical conductivity, turbidity and colour of water and calculating the Coliform and E-Coli, as two separate estimations, based on at least in part on the maximum total nitrogen, electrical conductivity, turbidity and colour value together with mean solar irradiance of the local of the water body.

[0007]

In one embodiment, at least one ammonium measurement is determined using in-situ sensors and subsequently calculating nitrogen from ammonium.

[0008]

In one embodiment the method includes obtaining the solar irradiance from meteorological data based on location of the water body.

[0009]

In one embodiment the method includes obtaining the meteorological data using at least one of: file transfer protocol (FTP); and; an application programming interface (API).

[0010]

In one embodiment the method includes: comparing the solar irradiance with monthly average for the location of the water body; and determining higher values for subsequent calculations.

[0011]

In one embodiment the method includes: receiving a plurality of EC, turbidity, colour from a plurality of sensors; determining all highest measurements from those plurality of measurements; and identifying those parameters as input parameters for the calculation of Coliforms and E-Coli.

[0012]

In one broad form an aspect of the present invention seeks to provide apparatus for use in performing on-line detection of Coliforms and E-Coli for a water body, the apparatus including: at least one sensor for each of the EC, turbidity, Colour, nitrates, nitrites and ammonium detection and a meteorological data source via one or more communications networks, the one or more electronic processing devices being configured to: receive, from the at least one sensor for each of the EC, turbidity, Colour, nitrates, nitrites and ammonium detection; in response to estimating Coliforms and E-Coli in water at any given instance: obtaining, from a meteorological data source, meteorological data for a geographical region corresponding to the location of water body for a prior time period.

[0013]

In one embodiment the one or more electronic processing devices are configured to provide an indication of the determined Coliforms and E-Coli area of water over the subsequent time period.

[0014]

In one embodiment the apparatus includes a plurality of EC, turbidity, colour, nitrates, nitrites and ammonium detection sensors, the plurality of EC, turbidity, colour, nitrates, nitrites and ammonium detection sensors being coupled together via a sensor communication network.

[0015]

In one embodiment the apparatus includes: a gateway unit configured to act as a parent node in the sensor communication network; and a plurality of sensor units each including a respective EC, turbidity, Colour, nitrates, nitrites and ammonium detection sensors and configured to receive the sensor communication network and transfer the EC, turbidity, Colour, nitrates, nitrites and ammonium detection measurements to the one or more electronic processing devices.

[0016]
In one embodiment the one or more electronic processing devices are coupled to the gateway unit and the meteorological data source via the Internet.

[0017]
It will be appreciated that the broad forms of the invention and their respective features can be used in conjunction, interchangeably and/or independently, and reference to separate broad forms is not intended to be limiting.

Brief Description of the Drawings

[0018]
Various examples and embodiments of the present invention will now be described with reference to the accompanying drawings, in which: -

[0019]
Figure 1 is a flow chart of an example of a method for use in both measuring input parameters and determining Coliforms and E-Coli;

[0020]
Figure 2 is a schematic diagram of an example of a distributed architecture;

[0021] Figure 3 is a schematic diagram of an example of a server processing system;

[0022] Figure 4 is a schematic diagram of an example of a client processing system; and

[0023] Figures 5A to 5C are a flow chart of an example of a method and apparatus for use in determining Coliforms and E-Coli on-line..

Detailed Description of the Preferred Embodiments

[0024]
An example of a method for use in measuring on-line Coliforms and E-Coli will now be described with reference to Figure 1.

[0025] The method will typically be performed using one or more electronic processing devices, which may be provided in the form of discrete devices such as servers or personal computers, or shared computer processing resources which may be obtained using Internet-based cloud computing services. The one or more electronic processing devices will typically be coupled to one or more communication networks to allow data to be received or transferred as required to perform the steps of the method.

[0026] In step 100, the method involves receiving, from at least one sensor measurement for EC, turbidity, colour, nitrates, nitrites and ammonium detection sensors, the plurality of EC, turbidity, colour, nitrates, nitrites and ammonium detection sensors, embodiments of the method may utilise a plurality of EC, turbidity, colour, nitrates, nitrites and ammonium detection sensors which may immersed in flowing water to allow multiple measurements to be obtained.

[0027] Step 110 involves then involves determining total nitrogen content based on the nitrates and nitrites.

[0028]

Step 120 Based on the ammonium measurement, calculate the nitrogen content from the ammonium.

[0029] Having obtained two separate nitrogen calculations from 110 and 120 above, the subsequent step 130 involves obtaining, from solar irradiance from meteorological data source, meteorological data for a geographical region corresponding to the water body location. The meteorological data source may be provided by an organisation that provides weather services, such as the Bureau of Meteorology in Australia. Typically, the meteorological data source will facilitate access to meteorological data such as weather observations and forecasts for different geographical regions. This access may be facilitated via the Internet, for instance by using File Transfer Protocol (FTP) or an Application Programming Interface (API). Accordingly, the meteorological data may be readily accessed via a suitable Internet-enabled interface of the meteorological data source.

[0030] In step 140, the method involves determining one value for the time period tested, as an average, along with meteorological data. The average values for the parameters from [100] may be determined in a variety of different ways, such as by calculating the mean values of the measured parameters. The solar irradiance value may be directly obtained from the meteorological data. In some cases, the solar irradiance values may be obtained using different sources/techniques should the data for the location is not available for a given time and day at the water source.

[0031] Next, step 150 involves calculating the Coliforms and E-Coli quantities based on part on water parameter data collected from [110] - [140].

[0032] Accordingly, Coliform and E-Coli quantities can be determined without the need for incubation, filtering techniques or any other time-consuming methods cited.

[0033] It should be noted in particular that the use of meteorological data for the time period to determine the solar irradiance value will mean that the water body has had an exposure of such irradiance over a period of time during the day.

[0034]

Further optional implementation features of the method will now be described.

[0035]

As mentioned above, the solar irradiance value may be determined in different ways, and thus in some implementations, the method may include determining a plurality of solar irradiance values using different techniques, determining a maximum solar irradiance value from the plurality of solar irradiance values; and then calculating the Coliforms and E-Coli based at least in part on the maximum solar irradiance value. This may provide a more conservative approach to ensure the Coliforms and E-Coli is calculated based on a highest solar irradiance scenario, and thus avoid the situation where a solar irradiance calculation based on a particular set of parameters might not accurately model the full extent of solar irradiance in certain circumstances. The use of a maximum solar irradiance insures possibility of under-estimating Coliforms and E-Coli which has a higher risk of inhibiting water quality.

[0036]

Implementations of the method may involve calculating solar irradiance values using the meteorological data, for instance by using known calculation methods such as the linear regression (LR), Angstrom-Prescott-Page (APP) and the artificial neural network (ANN) models

[0037]

For each of the above three models the basic dataset for a given location encompass solar radiation (H), minimum and maximum temperatures (Tmin and Tmax), total rainfall and evaporation (Lr and Le), and sunshine duration (S) over a period of time. A comprehensive dataset is available for many meteorological sites to get the monthly averages. This dataset is also important for ANN training and testing.

[0038]

The linear regression methods (LR) involves the following methodology:
The monthly average daily extra-terrestrial solar radiation, Ho, on a horizontal surface can be calculated from the following equation (Elminir et al., 2007):

$$H_0 = \frac{24 \times 3600}{\pi} I_0 k \left(cos\varphi cos\delta sin\omega + \frac{\pi\omega}{180} sin\varphi sin\delta \right)$$

where Io is the solar constant, k is the eccentric correction factor of the earth's orbit, φ is the latitude of the location (degrees), δ is the solar declination angle (degrees) and ω is the sunset hour angle (degrees). The currently accepted and commonly used Io value is set at 1367 W/m^2, which is recommended by the World Radiation Centre (Montero et al., 2009; Page, 1986; Stine, 1985). The eccentric correction factor k for each day can be calculated (Yorukoglu and Celik, 2006):

$$k = 1 + 0.033 cos\left(\frac{360 d_n}{365}\right)$$

where dn is the day number counted from beginning of the year (where dn = 1 for 1st of January).

The declination angle δ and sunset hour angle ω for each day of the year can be calculated below (Cooper, 1969; Luque and Hegedus, 2003):

$$\delta = 23.45 sin\left(\frac{360 \times (284 + d_n)}{365}\right)$$

$$\boldsymbol{\omega = cos^{-1}(-tan\varphi tan\delta)}$$

Lastly, the maximum possible sunshine duration, So, for each day is calculated from (Soler and Gopinathan, 1994):

$$\boldsymbol{S_0 = \frac{2}{15}\omega}$$

To gauge the accuracy of the models, the (RMSE) was used.

Linear Regression (LR) Analysis

Having established the values from mathematical equations above for each day, the averages were obtained which forms the linear regression model shown below:

$$\boldsymbol{H = aT_{min} + bT_{max} + cL_r + dL_e + eH_0 + f\frac{S}{S_0} + g}$$

where **a** to **g** are regression coefficients, to be determined empirically.

[0039]

On the other hand, the Angstrom-Prescott-Page (APP) method for calculating solar irradiance can be expressed using the formula:

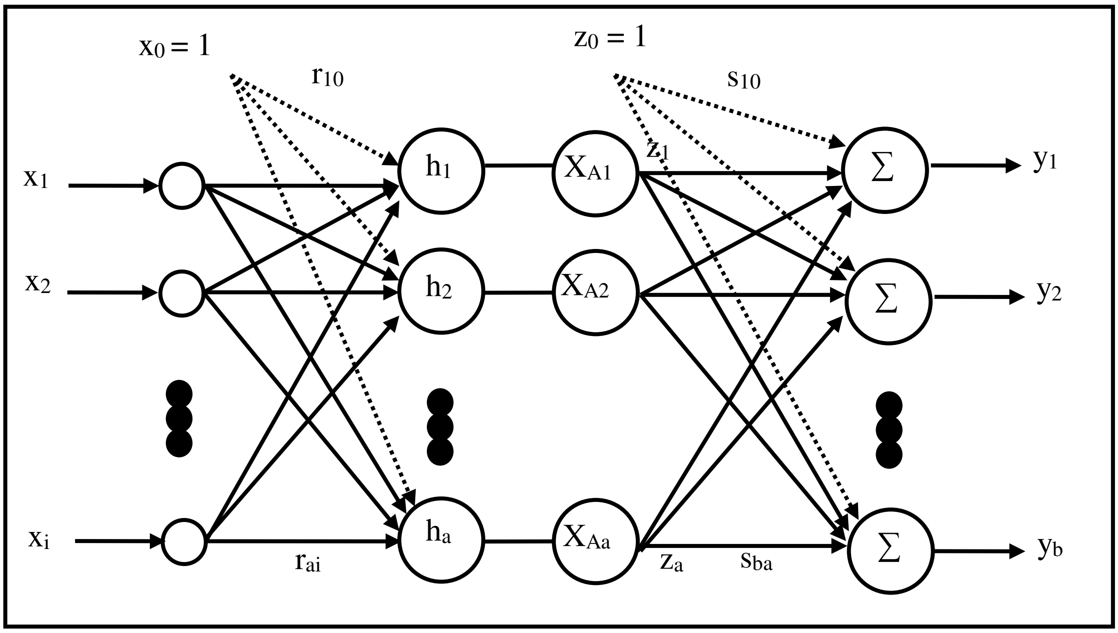
$$\frac{H}{H_0} = a + b\frac{s}{s_0}$$

where *a* and *b* are the empirical (or Angstrom) coefficients. The coefficient *a* can be interpreted as the fraction of the monthly average solar radiation (H/Ho) entering the atmosphere when there is a complete cloud cover (Ahmad and Tiwari, 2011). The second coefficient *b* defines the rate of change of H/Ho with respect to the sunshine duration ratio (S/So). It is an index of the latitudinal variation (Ahmad and Tiwari, 2011). To determine the values for coefficients *a* and *b*, the plot clearness index (H/Ho) vs. sunshine duration ratio (S/So) is plotted to get a linear trend-line.

[0040]

The OLL network was proposed and developed by Ergezinger and Thomsen. This method is based on the linearization of the activation function, thus leading to a linear optimization problem in each layer. The error made when linearizing the activation function is accounted for by introducing a penalty term. This penalty term, whose influence is varied, is to maintain optimum convergence for the network. The OLL neural network is then optimized in an iterative procedure, where for each iteration, the corresponding weights are optimized by solving a set of linear equations. It uses the

Figure below shows a basic OLL neural network structure. Inputs x_i are connected to the hidden layer with connect weights r_{ai} and the hidden neuron are connected to the output neurons with connection weights s_{ba}. The b neurons in the output layer have a pure linear activation function and hidden neurons have a sigmoid activation function. The training algorithm for the OLL model described below:



Optimization Layer-by-Layer ANN Architecture

Step 1: Initialization

Initial values for the weights R and S, where R and S are the weight vectors between the hidden-input and output-hidden layers respectively, penalty constant μ and the number of iterations are defined. Weight vectors R and S are to be optimized in order to minimize the error function.

Step 2: Optimization of Output Layer Weights

The optimum weight for S, $S^{optimum}$, is obtained using:

$$S^{optimum} = A^{-1} \bullet b$$

with

$$A = \sum_{p=1}^{P} z_a{}^p z_j{}^p \quad a, j = 0, \ldots, A$$

$$b = \sum_{p=1}^{P} z_a{}^p t^p \quad a = 0, \ldots, A$$

where P is the total number of training data, z_a^p and z_j^p are the scalar outputs of the hidden neurons of training data p and t^p is the target output value.

Update the weights S and calculate the RMS error using below:

$$Error_{RMS} = \frac{\sum_{p=1}^{P}\sum_{k=1}^{K}\left(t_k{}^p - y_k{}^p\right)^2}{PK}$$

where K is the total number of output neurons, t_k^p is the target output value for neuron k and training data p and y_k^p is the network output value for training data p.

Step 3: Optimization of Hidden Layer Weights

The new updated weight R is then defined as R^{test}, as shown:

$$\Delta R^{optimum} = \tilde{A}^{-1} \bullet \tilde{b}$$

where

$$for\ a \neq h$$

$$\tilde{A} = \sum_{p=1}^{P}\sum_{b=1}^{B}\left[\left(x_i s_{ba}{}^{linearized}\right)\left(x_m s_{bh}{}^{linearized}\right)\right]$$

$$where\, i, m = 0, \ldots, I \ h = 0, \ldots, A$$

$$for\, a = h$$

$$\tilde{A} = \sum_{p=1}^{P}\sum_{b=1}^{B}\left[\left(x_i s_{ba}{}^{linearized}\right)\left(x_m s_{bh}{}^{linearized}\right) + \frac{\mu}{A}\left|s_{ba}{}^{linearized}\right|\left\|X_{Aa}{}''\right| x_i x_m\right]$$

$$where\, i, m = 0, \ldots, I \ h = 0, \ldots, A$$

and

$$\tilde{b} = \sum_{p=1}^{P} \sum_{b=1}^{B} \left[(t^{p} - y_{b}) s_{bh}{}^{linearized} x_{m} \right]$$

$$where\ m = 0,\ldots, I\ h = 0,\ldots, A$$

where $s_{ba}{}^{linearized}$ and $s_{bh}{}^{linearized}$ are the linearized weights from neuron b of the output layer to neurons a and h in the hidden layer (of training data P), $X_{Aa}{}''$ is the second derivative of the activation function X_{Aa}, s_{ba} and s_{bh} are the connection weights between the output-hidden layer.

Once $\Delta R^{optimum}$ is obtained, the new update weight can be defined as:

$$R = R^{old} + \Delta R^{optimum}$$

Step 4: Test for Completion

RMS error, $E_{RMS}{}^{test}$, was then calculated comparing the R^{test} matrix with S or $S^{optimum}$ matrices calculated in Step 3.

a. $E_{RMS}{}^{test} < E$

   The hidden layer weight matrix R is updated $R = R^{test}$. Decrease the influence of the penalty term by decreasing μ. Proceed to Step 5.

b. $E_{RMS}{}^{test} \geq E$

   Increase the influence of μ and repeat Step 4a.

Step 5: Process Termination

If RMS error solar radiation is not within the desired range, repeat Step 2, else the training process is ceased.

[0041]

It will thus be appreciated that calculation of the solar irradiance value using the any of the three methods will require access to meteorological data including observations of a range of different measurements including the maximum temperature, the minimum temperature, the rain fall and evaporation.

[0042]

lternatively or additionally, the solar irradiance value may be determined based on a value calculated by the meteorological data source and included in the meteorological data. As mentioned above multiple techniques can be used and a highest value may be used for calculating the Coliforms and E-Coli.

[0043]

In order to more specifically account for the particular water body in the Coliform and E-Coli on-line calculation, the method may include determining a solar irradiance value for the particular location of the water body along with nitrogen from nitrates and nitrates and separate calculation of nitrogen from ammonium alone.

[0044]

In particular, this may involve determining nitrogen from ammonium as a separate calculation to nitrogen from nitrates and nitrite. In one example, the method may include determining, using the water parameters such as EC, turbidity and colour then determining the two nitrogen quantities in accordance with the identification of the parameters namely nitrates-nitrite or ammonium for subsequent calculation of Coliforms and E-Coli

[0045]

It should be appreciated that the particular set of water data that is stored may depend on the specific techniques used for determining the solar irradiance on water body value and/or the Coliforms and E-Coli. In any event, the water Coliforms and E-Coli data may be stored in a database or the like and in some examples may be organised into tables for each crop.

[0046]

It will be appreciated that the nitrogen from nitrates and ammonium is calculated using the formulas:

a) N-NO3 = Measured NO3 /4.43

b) N-Nh4 = Measured NH4*14/17

[0047]

With regard to the meteorological data, which is used for at least determining the solar irradiance value, this may be obtained based on location data for the water body. For example, a geographical location for a particular site to which this method is to be applied may be used to obtain meteorological data corresponding to that location. In some cases, meteorological data may only be available for neighbouring regions, and the method may either use meteorological data for the closest region or may use averaged values of the meteorological data for more than one neighbouring region if desired.

[0048]

Particular implementations of the method may include obtaining the meteorological data using file transfer protocol (FTP) or an application programming interface (API). The particular technique used for accessing the meteorological data will largely depend on the techniques supported by the meteorological data source.

[0049]

The specific types of meteorological data that may be obtained and used in the method include a relative humidity observation, a maximum temperature observation, a minimum temperature observation, an air temperature observation, a soil surface temperature observation, an atmospheric pressure observation, and a solar radiation exposure observation. The aforementioned observations can support the calculation of evapotranspiration values using the Priestly Taylor method or the Turc method as discussed above, but it should be appreciated that not all of these need to be obtained in all implementations of the method. On the other hand, additional types of meteorological data may also be obtained to support the use of other techniques or for providing extended functionalities.

[0050]

As mentioned above, solar irradiance value may be obtained directly as part of the meteorological data. This can be useful to allow comparisons to the values derived from other techniques, but it should be understood that this is not essential.

[0051]

In another aspect, an apparatus may be provided for use in performing on-line detection of Coliforns and E-Coli for a particular water body. The apparatus may include at least one sensor for each of the EC, turbidity, colour, nitrate, nitrite and ammonium in water, and one or more electronic processing devices coupled to the at least one or more of the above sensors and a meteorological data source via one or more communications networks. In this regard, the one or more electronic processing devices will be configured to perform the method as described above.

[0052]

In some implementations, the one or more electronic processing devices may be configured to provide an indication of the calculated Coliforms and E-Coli via app.

[0053]

As mentioned above, a plurality of sensors may be used, and in this respect the apparatus may include the plurality of sensors, which may be coupled together via a sensor communication network. In one example, the apparatus may include a gateway unit configured to act as a parent node in the sensor communication network and a plurality of sensor units. Each sensor unit may include a respective EC, turbidity, colour, nitrate, nitrite and ammonium sensors and be configured to act as a child node in the sensor communication network. The gateway unit may in turn be configured to receive measurements from the sensor units and transfer the moisture measurements to the one or more electronic processing devices.

[0054]

The one or more electronic processing devices may be coupled to the gateway unit and the meteorological data source via the Internet. In one specific embodiment, the one or more electronic processing devices may be provided using a cloud computing system and the meteorological data source may be accessed via an Internet API.

[0055]

In one example, the process is performed by one or more processing systems operating as part of a distributed architecture, an example of which will now be described with reference to Figure 2.

[0056]

In this example, the arrangement includes a number of processing systems 201, 203 along with gateway and sensor units 205, 207, each interconnected via one or more communications networks, such as the Internet 202, and/or a number of local area networks (LANs) 204.

[0057]

It will be appreciated that the configuration of the networks 202, 204 are for the purpose of example only, and in practice the processing systems 201, 203 and gateway and sensor units 205, 207 can communicate via any appropriate mechanism, such as via wired or wireless connections, including, but not limited to mobile networks, private networks, such as an 802.11 networks, the Internet, LANs, WANs, or the like, as well as via direct or point-to-point connections, such as Bluetooth, Zigbee or the like.

[0058]

The nature of the processing systems 201, 203 and their functionality will vary depending on their particular requirements. In one particular example, the processing systems 201, 203 represent servers (such as for determining the Coliforms and E-Coli) and clients (for allowing mining companies, water infrastructure companies, water recycling plants and aquaculture plants to monitor Coliforms and E-Coli processes or updating data), although this is not essential and is used primarily for the purpose of illustration.

[0059]

An example of a suitable processing system 201 is shown in Figure 3. In this example, the processing system 201 includes an electronic processing device, such as at least one microprocessor 300, a memory 301, an optional input/output device 302, such as a keyboard and/or display, and an external interface 303, interconnected via a bus 304 as shown. In this example the external interface 303 can be utilised for connecting the processing system 201 to peripheral devices, such as the communications networks 202, 204, databases 211, other storage devices, or the like. Although a single external interface 303 is shown, this is for the purpose of example only, and in practice multiple interfaces using various methods (e.g. Ethernet, serial, USB, wireless or the like) may be provided.

[0060]

In use, the microprocessor 300 executes instructions in the form of applications software stored in the memory 301 to perform required processes, such as communicating with other processing systems 201, 203 or the gateway and/or sensor units 205, 207 depending on the sensor network topology. Thus, actions performed by a processing system 201 are performed by the processor 300 in accordance with instructions stored as applications software in the memory 301 and/or input commands received via the I/O device 302, or commands received from other processing systems 201, 203. The applications software may include one or more software modules, and may be executed in a suitable execution environment, such as an operating system environment, or the like.

[0061]

Accordingly, it will be appreciated that the processing systems 201 may be formed from any suitable processing system, such as a suitably programmed computer system, PC, web server, network server, or the like. In one particular example, the processing system 201 is a standard processing system such as a 32-bit or 64-bit Intel Architecture based processing system, which executes software applications stored on non-volatile (*e.g.*, hard disk) storage, although this is not essential. However, it will also be understood that the processing systems 201 could be or could include any electronic processing device such as a microprocessor, microchip processor, logic gate configuration, firmware optionally associated with implementing logic such as an FPGA (Field Programmable Gate Array), or any other electronic device, system or arrangement.

[0062]

As shown in Figure 4, in one example, the processing systems 203 include an electronic processing device, such as at least one microprocessor 400, a memory 401, an input/output device 402, such as a keyboard and/or display, and an external interface 403, interconnected via a bus 404 as shown. In this example the external interface 403 can be utilised for connecting the processing system 203 to peripheral devices, such as the communications networks 202, 204, databases, other storage devices, or the like. Although a single external interface 403 is shown, this is for the purpose of example only, and in practice multiple interfaces using various methods (e.g. Ethernet, serial, USB, wireless or the like) may be provided.

[0063] I

n use, the microprocessor 400 executes instructions in the form of applications software stored in the memory 401 to perform required processes, for example to allow communication with other processing systems 201, 203. Thus, actions performed by a processing system 203 are performed by the processor 401 in accordance with instructions stored as applications software in the memory 402 and/or input commands received from a user via the I/O device 403. The applications software may include one or more software modules, and may be executed in a suitable execution environment, such as an operating system environment, or the like.

[0064]

Accordingly, it will be appreciated that the processing systems 203 may be formed from any suitable processing system, such as a suitably programmed PC, Internet terminal, lap-top, hand-held PC, smart phone, PDA, tablet, or the like. Thus, in one example, the processing system 203 is a standard processing system such as a 32-bit or 64-bit Intel Architecture based processing system, which executes software applications stored on non-volatile (*e.g.*, hard disk) storage, although this is not essential. However, it will also be understood that the processing systems 203 can be any electronic processing device such as a microprocessor, microchip processor, logic gate configuration, firmware optionally associated with implementing logic such as an FPGA (Field Programmable Gate Array), or any other electronic device, system or arrangement.

[0065]

It will also be noted that whilst the processing systems 201, 203 are shown as single entities, it will be appreciated that this is not essential, and instead one or more of the processing systems 201, 203 can be distributed over geographically separate locations, for example by using processing systems provided as part of a cloud based environment.

[0066]

In a preferred implementation, the processing systems 201 may be provided as part of a cloud computing service and will communicate with other elements of the arrangement via the Internet 202. The use of other processing systems 203 in the form of client devices is not essential to the method, but in practice will be advantageous to allow users such as Aquaculture farmers, water companies and mining companies, hospitals or the like to monitor the Coliforms and E-Coli status for a site. Furthermore, users can interact with the processing systems 201 or data stored on the database 211 to update data for use in the method, such as the input data or Coloforms data, if necessary.

[0067]

The gateway and sensor units 205, 207 may be provided as specialised versions of the processing systems 203 as shown in Figure 4, whereby the external interfaces 403 include dedicated sensor interfaces for interfacing with respective soil moisture sensors along with network interfaces as required for the particular sensor network topology. For instance, the gateway unit 205 may differ from the sensor units 207 in terms of the particular network connectivity provided. The gateway unit 205 may include external network connectivity for allowing communications with the processing systems 201 via the Internet or any other external network, along with internal network connectivity for enabling communications within a localised sensor network, such as by using Zigbee or any other suitable networking protocol. On the other hand, the sensor units 2017 may only include internal network connectivity.

[0068]
Since the gateway and sensor units 205, 207 may need to be deployed in remote locations these may include localised power sources such as a solar panel and rechargeable batteries. To conserve power, the microprocessor 400 and other hardware used in the gateway and sensor units 205, 207 may be selected for energy efficiency.

[0069] However, it will be appreciated that the above described arrangement is shown as an example only, and numerous other configurations may be used.

[0070] A detailed example of a method for use in on-line detection of Coliforms and E-Coli will now be described with regard to the flow chart of Figures 5A to 5B.

[0071] In this particular example, it is assumed that the main data processing functionalities of this method are provided as part of a cloud computing service which is able to communicate with meteorological data services and gateway and sensor units having respective soil moisture sensors via the Internet. This example will illustrate a typical loop of Coliform and E-Coli calculations which may be carried out periodically and potentially only at predetermined times of the day.

[0072] As an initial process, the method will involve checking the water field status at step 500. This may include accessing a water field table including particular information regarding a field such as coordinates, date, time, type of water. If the field status is inactive the method may proceed no further, however if the field status is active a determination may be made on whether the field status should be changed to inactive.

[0073] Assuming field status is active, type of water source such as fresh water, effluent, creek water, drinking water or brackish water selection should also be made at next step [501] at the field status.

[0074] EC, turbidity, colour, nitrate, nitrite, ammonium measurements will be received at step 502, and in the event that these are received for multiple soil moisture sensors in the same field, these may be processed by averaging or taking a maximum measurement.

[0075] At step 503 based on the sensory input and steady state collection, ensure the steady quantitative collection of the process parameters to avoid large variability.

[0076] At [504] meteorological data will be obtained for the day. In this example, the meteorological data may be obtained from three separate meteorological data sources via Internet APIs.

[0077] The maximum value of the solar irradiance/radiation data may be taken after processing the three models namely: Linear regression, APP and AI. The data is sent to the could at [506]

[0078] Moving on to step 507, the method may then include calculation of Coliforms and E-Coli in the cloud as function of EC, turbidity, Colour, nitrogen from nitrates, nitrite and ammonium along with the solar irradiance obtained from [504].

[0079] Throughout this specification and claims which follow, unless the context requires otherwise, the word “comprise”, and variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers or steps but not the exclusion of any other integer or group of integers.

[0080] Persons skilled in the art will appreciate that numerous variations and modifications will become apparent. All such variations and modifications which become apparent to persons skilled in the art, should be considered to fall within the spirit and scope that the invention broadly appearing before described.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1) A method for use in performing on-line measurement of Coliforms and E-Coli for a water body, the method being performed using one or more electronic processing devices, the method including:
   a) receiving, from one set of combined measurement of EC, turbidity, colour, nitrite, nitrite and ammonium and subsequent calculations of nitrogen from nitrite, nitrate along with nitrogen from aluminium as separate calculations.
   b) in response to sensory output in determining on-line Coliforms and E-Coli for a water body:
      i) obtaining, from a meteorological data source, meteorological data for a geographical region corresponding to the location of water body;
      ii) determining at least one solar irradiance value for the prior time period based on at least some of the meteorological data; and
2) A method according to claim 1, wherein the method includes:
   a) determining a plurality of solar irradiance values using different techniques;
   b) determining a maximum solar irradiance value from the plurality of solar irradiance values; and
   c) calculating the Coliforms and E-Coli as functions of EC, turbidity, colour, nitrate, nitrite and ammonium based at least in part on the maximum solar irradiance value.
3) A method according to any one of claims 1 and 2, wherein at least one evapotranspiration value is determined using at least one of:
   a) Solar irradiance value calculated using the meteorological data using regression analysis (RA) method.
   b) Solar irradiance value calculated using the meteorological data using Angstrom-Prescott-Page (APP) method; and
   c) Solar irradiance value calculated using the Artificial Neural Network Method (ANN).
   d) and solar irradiance value calculated by the meteorological data source and included in the meteorological data.
4) A method according to any one of claims 1 to 3, wherein the method includes obtaining the meteorological data based on location data for the water body.
5) A method according to any one of claims 1 to 4, wherein the method includes obtaining the meteorological data using at least one of:

a) file transfer protocol (FTP); and;
b) an application programming interface (API).

6) A method according to any one of claims 1 to 5, wherein the meteorological data includes at least one of:
a) A minimum temperature observation;
b) a maximum temperature observation;
c) a minimum rainfall observation;
d) a maximum rainfall observation;
e) a maximum evaporation observation;
f) a minimum evaporation observation;
g) a solar radiation exposure observation.

7) Apparatus for use in performing on-line Coliform and E-Coli estimation for a water body, the apparatus including:
a) at least one sensor measurement for EC, turbidity, colour, nitrate and nitrite and ammonium; and
b) one or more electronic processing devices coupled to the at least one sensor for EC, turbidity, colour, nitrate and nitrite and ammonium and a meteorological data source via one or more communications networks, the one or more electronic processing devices being configured to:
   i) receive, from the at least one EC, turbidity, colour, nitrate and nitrite and ammonium measurement;
      (a) the at least one solar irradiance value.
      (b) Calculate nitrogen content for nitrates, nitrites and ammonium.
      (c) estimating most probable number of Coliforms and E-Coli per 100 millilitres of water as two separate calculations

8) Apparatus according to claim 6 or claim 7, wherein the apparatus includes a plurality of EC, turbidity, colour, nitrate and nitrite and ammonium sensors, the plurality of EC, turbidity, colour, nitrate and nitrite and ammonium being coupled together via a sensor communication network.

9) Apparatus according to claim 8, wherein the apparatus includes:
a) a gateway unit configured to act as a parent node in the sensor communication network; and

b) a plurality of sensor units each including a respective EC, turbidity, colour, nitrate and nitrite and ammonium sensor and configured to act as a child node in the sensor communication network, the gateway unit being configured to receive measurements from the sensor units and transfer the moisture measurements to the one or more electronic processing devices.

10) Apparatus according to claim 9, wherein the one or more electronic processing devices are coupled to the gateway unit and the meteorological data source via the Internet.

ABSTRACT

A method for use in performing on-line detection of Coliforms and E-Coli with a particular water body, the method being performed using one or more electronic processing devices, the method including: receiving, from at least one set of measurements from EC, turbidity, colour, nitrate and nitrite and ammonium sensors located in water; determining whether steady state measurements obtained over a period of time; in response to determining input parameters for calculations required, obtaining, from a meteorological data source, meteorological data for a geographical region corresponding to the area of water for a prior time period; determining at least one solar irradiance value for the prior time period based on at least some of the meteorological data; and calculating the Coliforms and E-Coli quantity on-line based at least one set of the EC, turbidity, colour, nitrate and nitrite and ammonium and solar irradiance measurements; estimating most probable number of Coliforms and E-Coli per 100 millilitres of water as two separate calculations

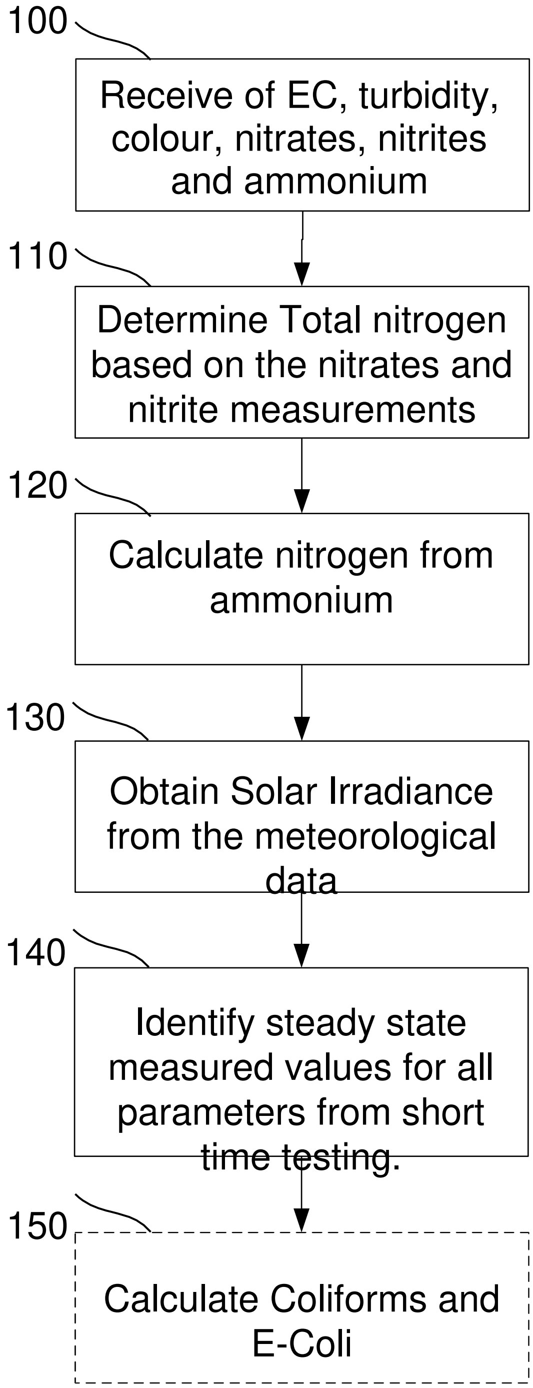

100
Receive of EC, turbidity, colour, nitrates, nitrites and ammonium
110
Determine Total nitrogen based on the nitrates and nitrite measurements
120
Calculate nitrogen from ammonium
130
Obtain Solar Irradiance from the meteorological data
140
Identify steady state measured values for all parameters from short time testing.
150
Calculate Coliforms and E-Coli

Fig. 1

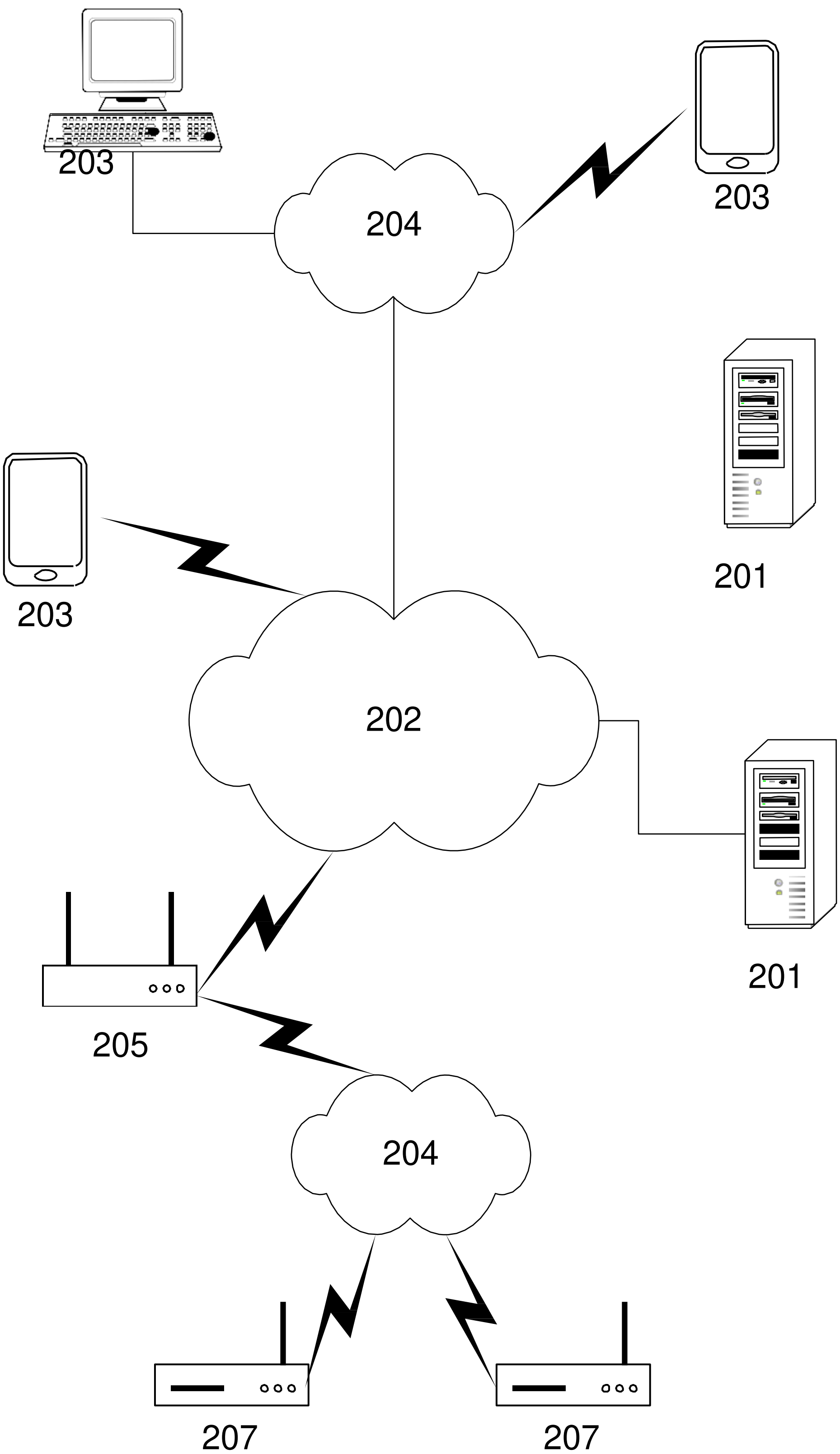


Fig. 2

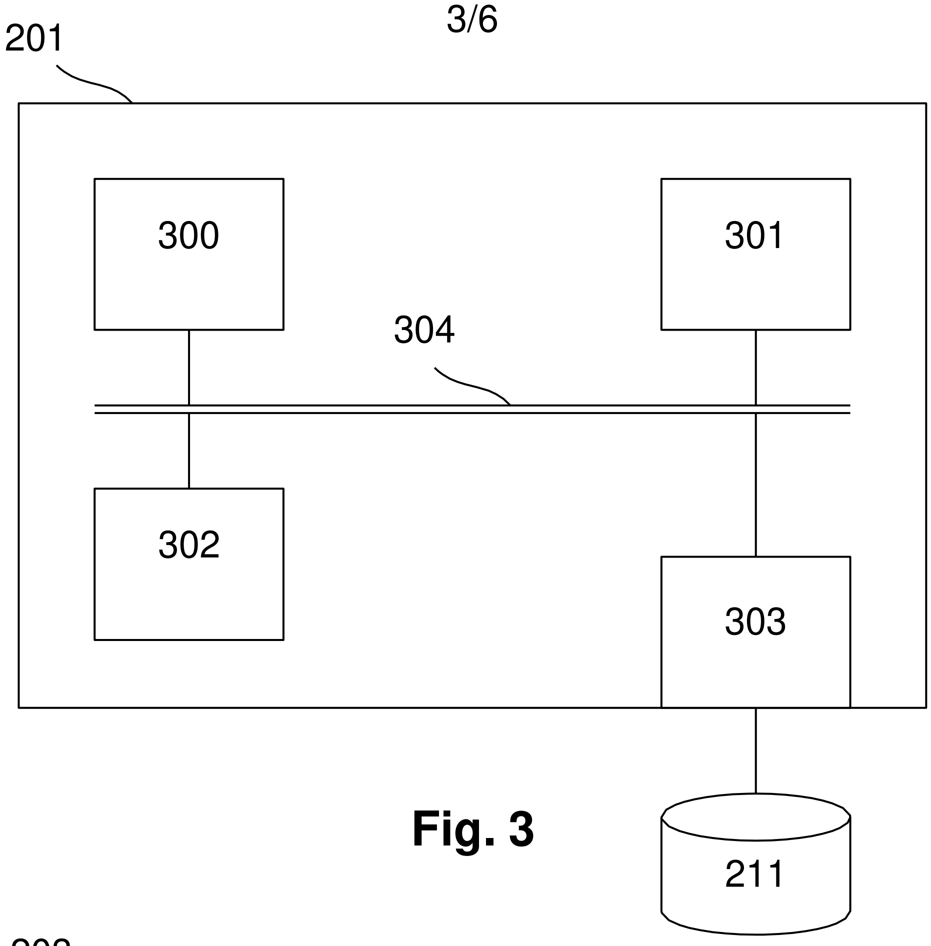


Fig. 3

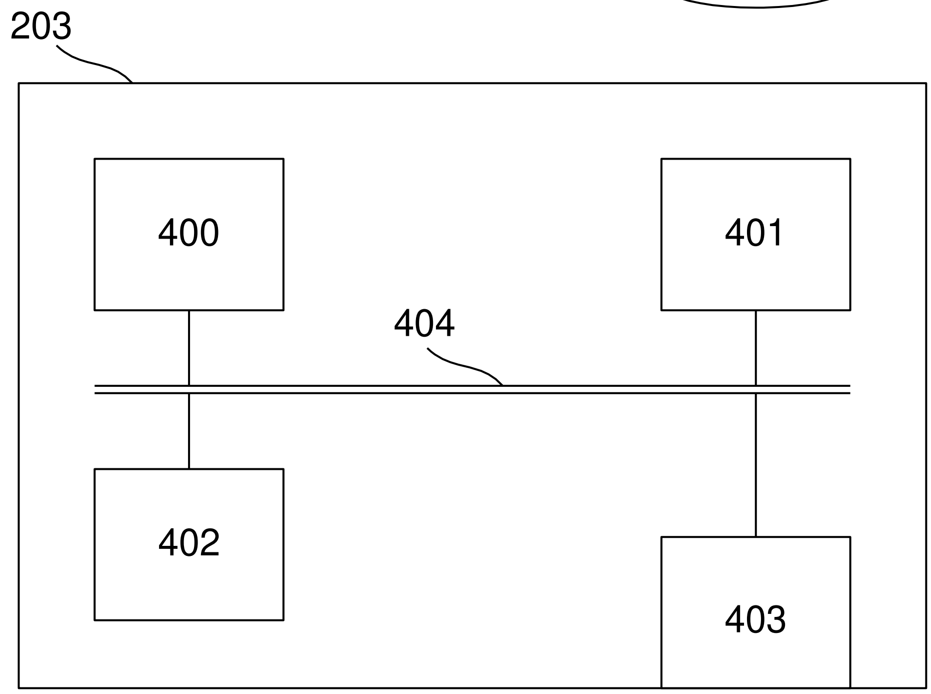


Fig. 4

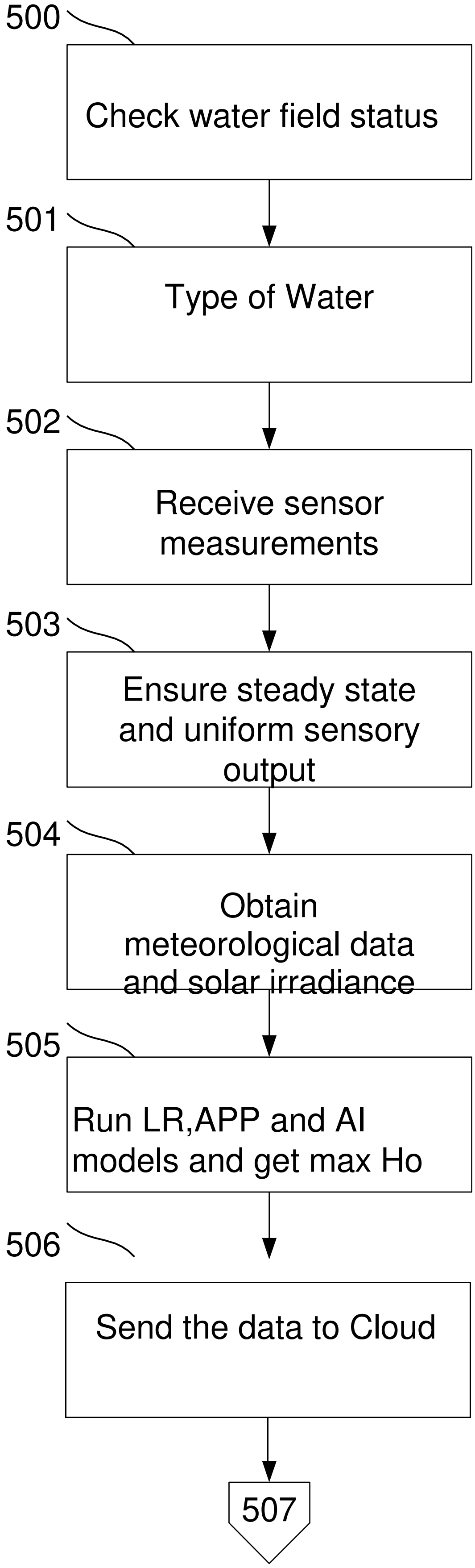

500
Check water field status
501
Type of Water
502
Receive sensor measurements
503
Ensure steady state and uniform sensory output
504
Obtain meteorological data and solar irradiance
505
Run LR,APP and AI models and get max Ho
506
Send the data to Cloud
507

Fig. 5A

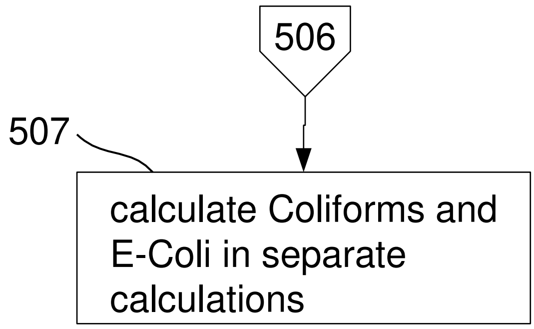

506
507
calculate Coliforms and E-Coli in separate calculations

Fig. 5B

[506]

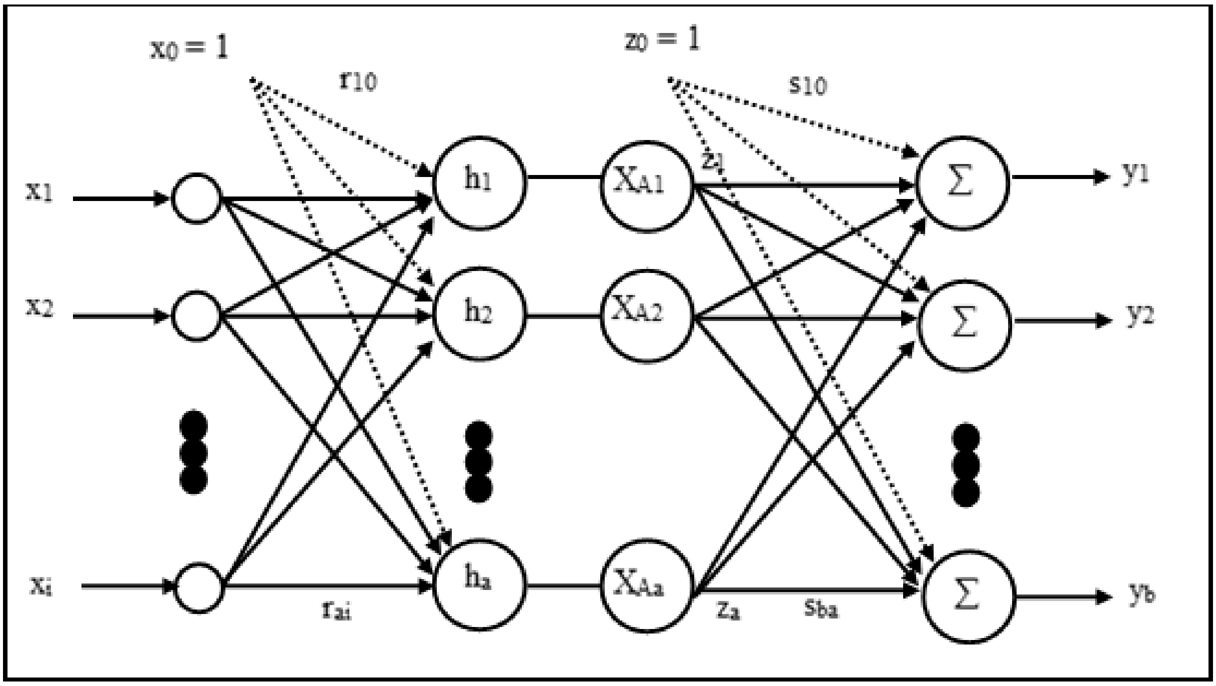


Fig: 5C Optimised layer by layer network